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INEEL CERCLA Disposal Facility Short-Term Risk Assessment

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The evaluations presented in this document focus exclusively on the nature, magnitude, and probability of actual or potential risks to human receptors. Given a variety of possible exposure scenarios, these evaluations define the potential doses to which different individuals may be exposed.

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	R/A	Typed Name/Organization	Signature	Date
Author		Donna Morgans/ CH2M HILL	Donna L Morgans	2/01/03
Author		Rich Weiss/ CH2M HILL	Richard L Weiss	2/01/03
Author		Roberta Day/ CH2M HILL	Roberta F. Day	2/01/03
Checker	R	(Same as Independent Peer Reviewer)		2/01/03
Independent Peer Reviewer	A	Marty Doornbos/ BBWI	Martin Doornbos	2/01/03
Doc. Owner	A	Tom Borschel/ ICDF PE	Thomas F. Borschel	2/01/03
Requestor	Ac	Dan Crisp/ BBWI	Dan E Crisp	2/01/03
Doc. Control	AC	Annie Buttars/ERDC	Annie Buttars	~~1/24/03~~ 02/03/03 DMB.

6. Distribution: (Name and Mail Stop) M. Doornbos, MS 3930; D. Crisp, MS 3930; T. Borschel, MS 3930

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ABSTRACT

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The evaluations presented in this document focus exclusively on the nature, magnitude, and probability of actual or potential risks to human receptors. Given a variety of possible exposure scenarios, these evaluations define the potential doses to which different individuals may be exposed.

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ACRONYMS

ACL	administrative control level
ALARA	as low as reasonably achievable
CDI	chronic daily intake
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Resource, Compensation and Liability Act
CFA	Central Facilities Area
CFR	Code of Federal Regulations
COPC	contaminant of potential concern
CSF	cancer slope factor
DF	dilution factor
DOE	Department of Energy
EDE	effective dose equivalent
EDF	Engineering Design File
ELCR	excess lifetime cancer risk
EPA	Environmental Protection Agency
EPC	exposure point concentration
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HLC	Henry's Law Constant
HQ	hazard quotient
ICDF	INEEL CERCLA Disposal Facility
INEEL	Idaho National Engineering and Environmental Laboratory
IRIS	Integrated Risk Information System
NCEA	National Center for Environmental Assessment
PCB	polychlorinated biphenyl

PEF	air particulate emission factor
RME	reasonable maximum exposure
TEDE	total effective dose equivalent
VOC	volatile organic compound
WAC	Waste Acceptance Criteria

INEEL CERCLA Disposal Facility Short-Term Risk Assessment

1. PURPOSE AND SCOPE

This document presents the results of the short-term (e.g., public and worker) risk assessment for the INEEL CERCLA Disposal Facility Complex (ICDF) pursuant to the National Contingency Plan (40 CFR 300). The baseline risk assessment consists of a human health risk assessment; an ecological risk assessment was submitted with the ICDF Final Remedial Design/Construction Work Plan and will not be addressed in this document.

The risk assessment considers exposure to ICDF Complex operators and the public to modeled concentrations of radioactive and nonradioactive hazardous substances representative of the ICDF landfill, the evaporation pond with two cells, and the decon building. The assessment also considers the exposure to the ICDF Landfill Waste Acceptance Criteria (WAC) concentration guides as a method to assist in determining a bounding risk for the proposed visitor. The time period bounding the risk assessment is the operational life of the ICDF Complex. This assumes a 15-year design life of the landfill disposal cell and the decon building, and a total of 45 years for the evaporation pond. The landfill will be covered after 15 years and the decon building and staging areas will be clean-closed, therefore contributing no further exposure. The latter period includes the 15-year operational period, plus an additional 30 years of ICDF postclosure operation to handle any leachate that may be generated following final cover of the landfill.

The remainder of this risk assessment is presented in four major sections: Section 2, Summary of Results; Section 3, Risk Assessment Methodology; Section 4, Radiological Analysis Results; and Section 5, Nonradiological Analysis Results. These sections are supported by additional information in Appendixes A through D. The radionuclide elimination screening process, as an example, is illustrated in Appendix C, Table C-1. The selected radionuclides for each operational facility analyzed are then presented, with associated exposure point concentrations (EPC), in Appendix A, Table A-1. Exposure calculations estimates of receptor exposures are then shown separately in Section 4, using the selected radionuclides. For nonradiological constituents, however, the receptor exposures calculations are shown in Appendix D, and are then carried forward to Section 5 in summary form.

For purposes of this evaluation, target risk levels were established separately for radiological and nonradiological risks rather than calculated into a cumulative level (that is, summing the risks for radiological and nonradiological constituents for each scenario). This approach enables the identification of primary contributors for both the radiological and nonradiological constituents. Those constituents identified as primary contributors shall be included in the ICDF Complex documents. Section 6 of this document discusses and provides a reference to the ICDF Complex radiological controls, whereas the Health and Safety Plan (HASP) (INEEL 2003) addresses the nonradiological controls. These primary risk contributors will be considered for each exposed receptor, with additional briefing and awareness provided to those non-worker receptors regarding the anticipated modeled risks associated with site activities, as described in the HASP.

2. SUMMARY OF RESULTS

This section provides a summary of the results for the radiological and nonradiological risk evaluation conducted for the identified ICDF Complex operations and public exposure scenarios. For purposes of this evaluation, target risk levels were established separately for radiological and nonradiological risks rather than calculated into a cumulative level. However, for each exposure scenario, cumulative risks are calculated for multiple constituents (i.e., either radiological or nonradiological) and multiple exposure pathways. As noted below, the radiation dose limit of 15 mrem/year for public exposure scenarios is approximately equivalent to an estimated excess lifetime cancer risk of 1×10^{-4}.

2.1 Target Risk Levels for the Radiological Risk Evaluation

Radiological risk is characterized by comparison with regulatory limits and administrative control levels (ACLs). The regulatory limit for radiological workers and members of the public are specified in Title 10, Code of Federal Regulations, Part 835 (10 CFR 835), Occupational Radiation Protection.

In addition to the limits specified in 10 CFR 835, the Idaho National Engineering and Environmental Laboratory (INEEL) Radiological Control Manual conservatively imposes an initial ACL of 0.7 rem/year (DOE 1996). In no event can a worker receive in excess of 5 rem/year for normal operations (10 CFR 835). The radiation dose limits for exposure scenarios evaluated in this Engineering Design File (EDF) are provided below:

- The radiation dose limit for the unrestricted public exposure scenario (i.e., Highway 26 Rest Area visitor) and the member of the public entry (i.e., INEEL visitor, ICDF visitor) is 0.015 rem/year. This dose limit is developed for members of the public who are unknowingly exposed to radiation and is approximately equivalent to an excess lifetime cancer risk (ELCR) of 1×10^{-4}.

- The radiation dose limit for the general employees is 0.1 rem/year (10 CFR 835). This dose limit is developed for those members of the public who have received radiation training/briefing, and understand and are willing to accept the risks of radiation exposure.

- The radiation dose limit for the radiation worker exposure scenarios (e.g., ICDF Complex operators) is 5 rem/year (10 CFR 835).

2.2 Target Risk Levels for the Nonradiological Risk Evaluation

In interpreting estimates of ELCR, the Environmental Protection Agency (EPA) under Comprehensive Environmental Resource, Compensation and Liability Act (CERCLA) generally considers action to be warranted when risks exceed 1×10^{-4} (e.g., target risk level). Action generally is not required for risks falling within 1×10^{-6} and 1×10^{-4}; however, this is judged on a case-by-case basis as shown in Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals) (EPA 1991). Risks less than 1×10^{-6} are generally regarded by the Agencies as acceptable and do not need further consideration. For noncarcinogenic contaminants of potential concern (COPCs), a hazard quotient (HQ) or hazard index (HI) greater than 1 indicates that there is some potential for adverse noncancer health effects associated with exposure to ICDF Complex COPCs. COPCs and associated exposure point concentrations are discussed in Section 3.

2.3 Summary of Evaluation

2.3.1 Summary of Risk Estimates for Radiation Worker (II) Exposure Scenarios

Five worker scenarios were evaluated and a summary of the total effective dose equivalents (TEDE) for radiation exposures and cancer (ELCR) and noncancer (HI) risk estimates for nonradiation exposures are presented in Table 2-1 for each of the identified radiation worker exposure scenarios.

Table 2-1. Summary of TEDE and risk estimates for radiation worker exposure scenarios.

	Radiation	Nonradiation	
Exposure Scenario	TEDE (rem/year)	Noncancer HI	ELCR
Landfill bulldozer operator	4.4 E + 00	4.0 E - 01	8.0 E - 06
Landfill laborer	1.5 E + 01	4.0 E - 01	8.0 E - 06
Landfill truck driver	6.6 E + 00	4.0 E - 01	8.0 E - 06
Treatment operator	3.6 E - 02	9.0 E - 01	1.0 E - 05
Evaporation pond operator	1.9 E - 02	4.0 E + 00	1.0 E - 07
Target risk levels	5.0 E + 00	1.0 E + 00	1.0 E - 04

With the exception of the landfill laborer and truck driver, the TEDE for each receptor evaluated under the radiation worker exposure scenarios are less than the radiation dose limit of 5 rem/year. The TEDE for the landfill laborer and truck driver exceeds the radiation dose limit of 5 rem/year.

It is important to note that the TEDE values calculated for the landfill laborer are based on unmitigated risk. In no event will radiation workers be allowed to exceed the regulatory limit of 5 rem/year for occupational exposures. Section 6 of this document summarizes the approach for mitigating radiation risk at the INEEL to administrative levels as far below the regulatory limits as reasonably achievable.

The potential cumulative ELCR from nonradiological carcinogenic COPCs are less than the target risk level of 1×10^{-4}. With the exception of the evaporation pond operator, the potential HI for noncancer effects is less than or equal to 1 for all ICDF Complex exposure scenarios. The HI for noncancer effects for the evaporation pond operator is 4; the primary contributors to noncancer risk are 2-nitroaniline, 3-nitroaniline, and 4-nitroaniline. The project HASP adequately addresses mitigative measures associated with these constituents.

2.3.2 Summary of Risk Estimates for General Employee Radiation Training Worker Exposure Scenarios

A summary of the TEDE for radiation exposures and cancer (ELCR) and noncancer (HI) risk estimates for general employee radiation training worker exposures are presented in Table 2-2 for each of the identified exposure scenarios.

Table 2-2. Summary of TEDE and risk estimates for nonradiation worker exposure scenarios.

	Radiation	Nonradiation	
Exposure Scenario	TEDE (rem/year)	Noncancer HI	ELCR
ICDF office worker	<1.0 E - 03	<1.0 E - 02	5.0 E - 09
CFA office worker	<1.0 E - 03	<1.0 E - 02	3.0 E - 12
Delivery driver	<1.0 E - 03	<1.0 E - 02	4.0 E - 09
INEEL worker (power line management)	8.0 E - 03	2.0 E - 02	3.0 E - 07
Target risk levels	1.0 E - 01	1.0 E + 00	1.0 E - 04

The TEDE for the nonradiation worker scenarios are far below the radiation dose limit of 0.1 rem/year. It is important to note that the TEDE values calculated for the nonradiation worker exposure scenarios are based on unmitigated risk. In no event will workers be allowed to exceed the regulatory limit of 0.1 rem/year for occupational exposures. Section 6 of this document summarizes the approach for mitigating radiation risk at the INEEL to administrative levels as far below the regulatory limits as reasonably achievable.

The potential cumulative ELCR from nonradiological carcinogenic COPCs are less than the target risk level of 1×10^{-4}. The potential HI for noncancer effects is less than 1 for each nonradiation worker exposure scenario.

2.3.3 Summary of Risk Estimates for Member of the Public Entry Exposure Scenario

A summary of the TEDE for radiation exposures, cancer (ELCR), and noncancer (HI) risk estimates for the escorted member of the public entry exposures is presented in Table 2-3.

Table 2-3. Summary of TEDE and risk estimates for member of the public entry exposure scenarios.

	Radiation	Nonradiation	
Exposure Scenario	TEDE (rem/year)	Noncancer HI	ELCR
INEEL visitor	7.0 E – 03	<1.0 E - 02	3.0 E - 08
ICDF visitor	4.0 E - 02	9.0 E - 02	1.0 E - 07
Target risk levels	1.5 E - 02	1.0 E + 00	1.0 E - 04

The TEDE for the INEEL visitor is below the radiation dose limit of 0.015 rem/year. The INEEL visitor was assumed to be exposed to the entire ICDF Landfill WAC constituent concentrations. The TEDE for the ICDF visitor exceeds the radiation dose limit of 0.015 rem/year. The ICDF visitor was assumed to be exposed to the design inventory constituent concentrations only. The WAC constituent concentrations, in some instances, are many orders of magnitude greater than the design inventory constituent concentrations.

The TEDE values calculated for these exposure scenarios are based on unmitigated risk. Section 6 addresses the controls that will be implemented to ensure that visitors will be within the dose constraints.

The potential cumulative ELCR from nonradiological carcinogenic COPCs is less than the target risk level of 1×10^{-4}. The potential HI for noncancer effects is less than 1 for each nonradiation exposure scenario.

2.3.4 Summary of Risk Estimates for the General Public Exposure Scenario

The unrestricted general public exposure scenario considers exposure to a visitor located at the Highway 26 Rest Area. This unrestricted exposure scenario is a qualitative analysis based on the results of the INEEL visitor scenario. The INEEL visitor is in proximity to the ICDF Complex and shares the same source inventory and concentrations as the Highway 26 Rest Area exposed individual. The TEDE for the INEEL visitor is less than the radiation dose limit of 0.015 rem/year. Since the rest area is considerably farther (5,630 m) from the ICDF landfill than the INEEL visitor (300 m), and exposure decreases with distance, dose estimates calculated for the INEEL visitor are also considered protective of the Highway 26 Rest Area.

2.4 Uncertainty Analysis

Several sources of uncertainty affect the overall estimates of excess lifetime cancer risk and noncancer hazard as presented in this risk evaluation. The sources are generally associated with sampling and analysis, exposure assumptions, toxicity values, and risk characterization, and are summarized in Table 2-4.

2.4.1 Uncertainty Associated with Environmental Sampling and Analysis

Uncertainties associated with sampling and analysis include the inherent variability (standard error) in the analysis, representativeness of the samples, sampling errors, and heterogeneity of the sample matrix. While the quality assurance/quality control program used in conducting the sampling and analysis serves to reduce errors, it cannot eliminate all errors associated with sampling and analysis.

2.4.2 Uncertainty Associated with Exposure Assessment

Future soil EPCs were assumed to be equal to existing soil concentrations (i.e., design inventory). This assumption does not account for fate and transport processes likely to occur in the future; risk estimates are likely to be overestimated for future exposure scenarios. In addition, this does not take into account that the waste acceptance criteria are greater than the existing soil concentrations.

The estimation of exposure requires many assumptions to describe potential exposure situations. There are uncertainties regarding the likelihood of exposure, frequency of contact with contaminated media, the concentration of contaminants at exposure points, and the time period of exposure. These tend to simplify and approximate actual site conditions. In general, these assumptions are intended to be conservative and yield an overestimate of the true risk or hazard.

EPA default exposure assumptions and some site specific assumptions were conservatively used to estimate the potential worker and visitor scenarios. The assumptions do not take into account planned mitigative measures typically utilized during the operational activities (e.g., as low as reasonably achievable [ALARA], dust suppression).

2.4.3 Uncertainty Associated with Toxicity Assessment

The toxicological database was also a source of uncertainty. EPA has outlined some of the sources of uncertainty in the Risk Assessment Guidance for Superfund (EPA 1991). These sources may include or result from the extrapolation from high to low doses and from animals to humans; the species, gender, age, and strain differences in a toxin's uptake, metabolism, organ distribution, and target site susceptibility; and the human population's variability with respect to diet, environment, activity patterns, and cultural factors.

Surrogate toxicity values were used for detected chemicals without toxicity factors. Pyrene was selected as a surrogate for benzo(g,h,i)perylene and anthracene was selected as a surrogate for phenanthrene. Use of surrogate toxicity factors assumes the toxicity of structurally similar compounds is equivalent, this may result in an underestimate or overestimate of risks at the site.

2.4.4 Uncertainty Associated with Risk Characterization

In the risk characterization, the assumption was made that the total risk of developing cancer from exposure to site contaminants is the sum of the risk attributed to each individual contaminant. Likewise, the potential for the development of noncancer adverse effects is the sum of the estimated exposure to each individual contaminant. This approach, in accordance with EPA guidance, did not account for the possibility that constituents act synergistically or antagonistically.

Table 2-4. Uncertainties associated with human health risk estimations.

Uncertainty Factor	Effects of Uncertainty	Comment
Environmental Sampling and Analysis		
Estimates of constituent concentrations	May underestimate or overestimate risk	Sampling errors, sample representativeness, and variability in chemical analyses will affect chemical concentrations. Available analytical data may not accurately reflect site conditions. Chemical concentrations may change as a result of migration or degradation.
Exposure Assessment		
Source concentrations assumed constant over time	May underestimate or overestimate risk	Did not account for environmental fate, transport, or transfer, which may alter contaminant concentrations.
Source concentrations assumed based on design inventory	May underestimate risk	The waste acceptance criteria concentrations are in most cases above that of the design inventory. As such, the risk may be underestimated.
Exposure assumptions	May underestimate or overestimate risk	Assumptions regarding media intake, population characteristics, and exposure patterns may not characterize exposures.
Use of applied dose to estimate risks	May overestimate or underestimate risks	Assumes that the absorption of the chemical is the same as it was in the study that derived the toxicity value. Assumes that absorption is equivalent across species (animal to humans). Absorption may vary with age and species.
Population characteristics	May overestimate or underestimate risks	Assumes weight, lifespan, and ingestion rate are potentially representative for a potentially exposed population.
Intake	May underestimate risks	Assumes all intake of constituents are from the exposure medium being evaluated (no relative source contribution).

Table 2-4. (continued).

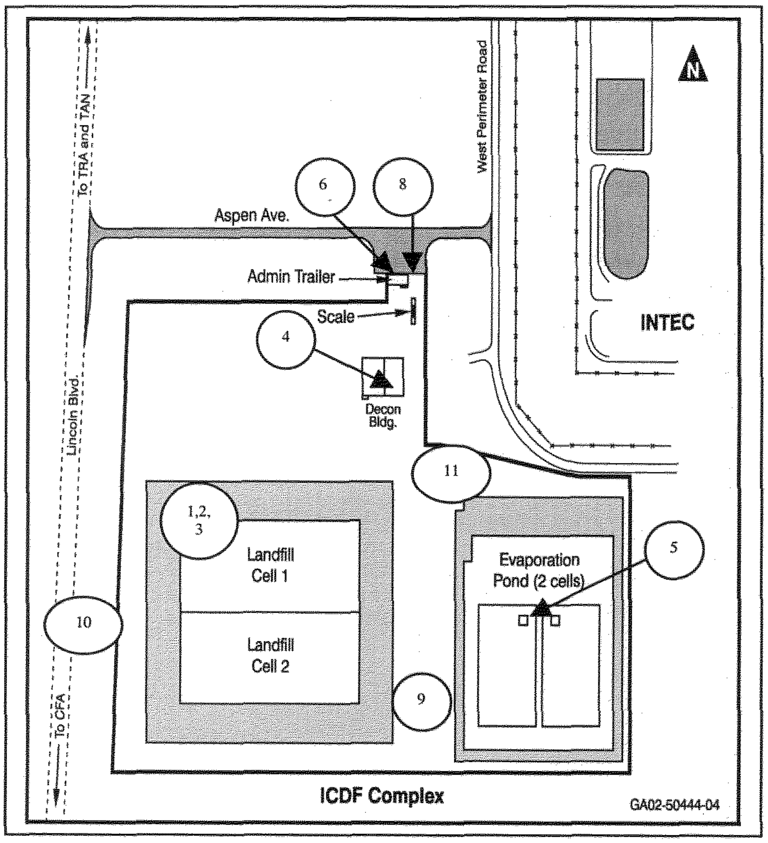
Uncertainty Factor	Effects of Uncertainty	Comment
Toxicity Assessment		
Slope factor	May overestimate risks	Slope factors are upperbound UCLs derived from a linearized model. Considered unlikely to underestimate risk.
Toxicity values derived from animal studies	May overestimate or underestimate risks	Extrapolation from animal to humans may induce error because of differences in pharmacokinetics, target organs, and population variability.
Toxicity values derived primarily from high doses (most exposures are at low doses)	May overestimate or underestimate risks	Assumes linearity at low doses. Tends to have conservative exposure assumptions.
Toxicity values	May overestimate or underestimate risks	Not all values represent the same degree of certainty. All are subject to change, as new evidence becomes available.
Toxicity data not available for all constituents	Risks could not be estimated	Potential negative effects of exposure to these constituents are not quantifiable.
Surrogate toxicity values	May overestimate or underestimate risks	Assumes toxicity of structurally similar compound is equivalent.
Toxicity values derived from short-term tests to predict chronic exposures	May overestimate or underestimate risks	Assumes that the dose-response observed from short-term exposure to high concentrations is similar to exposure to low concentration environmental exposures.
Toxicity values derived from homogeneous animal populations	May overestimate or underestimate risks	Human populations may have a wide range of sensitivities to a chemical.
Risk Characterization		
Estimation of risks across exposure routes	May underestimate or overestimate risk	Some exposure routes have greater uncertainty associated with their risk estimates than others.
Cumulative risk estimates	May underestimate or overestimate risk	Assumes additivity of risks from multiple chemicals; may have synergistic or antagonistic effects.
Cancer risk estimates (no threshold assumed)	May overestimate risks	Possibility that some thresholds do exist.
Cancer risk estimate (low dose) linearity	May overestimate risks	Response at low doses is not known.

3. RISK ASSESSMENT METHODOLOGY

The methodology for the ICDF Complex risk assessment employed exposure scenarios, exposure assumptions, risk calculation methodology, and data used in the risk assessment, as described in the following sections.

3.1 Exposure Scenarios

The risk assessment includes a range of exposure scenarios that capture various receptors associated with the ICDF Complex. Included are five Radiation Worker II exposure scenarios, four general employee radiation training worker exposure scenarios, two member of the public entry exposure scenarios, and one general public exposure scenario, as shown in Figure 3-1. A summary of these scenarios is presented in Table 3-1. A more detailed description of each scenario is provided in the following sections.



Radiation Worker II

1. Landfill bulldozer operator
2. Landfill laborer
3. Landfill truck driver
4. Treatment unit operator
5. Evaporation pond operator

General Employee Radiation Training Worker

6. ICDF office worker
7. CFA office worker (not shown)
8. Delivery driver
9. INEEL worker

Member of the Public Entry

10. INEEL visitor
11. ICDF visitor (assumed at each area)

General Public

12. Highway 26 Rest Area visitor (not shown)

Figure 3-1. ICDF Complex exposure scenario exposed individual locations.

Table 3-1. Summary of exposure scenarios.

Exposure Scenario	EPC Source: Concentration Source	EPC Source: Inventory Source	Distance From Source (m)	Shielding	Duration (yrs)	Frequency (days/ year)	Time (hrs/ day)	Exposure Routes: Direct Radiation	Exposure Routes: Incidental Ingestion	Exposure Routes: Dermal Contact	Exposure Routes: Inhalation
Radiation Worker II											
Landfill bulldozer operator	Design [a]	Landfill	1.5	1.3 cm Iron	15[b]	158[c]	10	✔	✔	✔	✔
Landfill laborer (walking on landfill cell surface)	Design [a]	Landfill	1	None	15[b]	158[c]	10	✔	✔	✔	✔
Landfill truck driver	Design [a]	Landfill	1.5	0.006 m Iron, 0.15 m clean soil	15[b]	158[c]	10	✔	✔	✔	✔
Treatment unit operator	Design [a]	Treatment waste	Varies	None	15[b]	200[d]	10	✔	✔	✔	✔
Evaporation pond operator	Design [a]	Evap Pond	2 Above 2 From Edge	None	25[e]	200[d]	2	✔			✔
General Employee Radiation Training Worker											
ICDF office worker	Design [a]	Landfill, Treatment waste	100 63	Berm, None	15[b]	200[d]	10	✔			✔
CFA office worker	Design [a]	Landfill	4000	None	15[b]	200[d]	10	✔			✔
Delivery driver	Design [a]	Landfill, Treatment waste	100 63	Berm, None	15[b]	200[d]	1	✔			✔
INEEL worker (power line management)	Design [a]	Landfill, Evap Pond	12 (Pole)	Berms	15[b]	10	8	✔			✔
Member of the Public Entry											
INEEL visitor	WAC [f]	Landfill	85	Berm	15[b]	10	8	✔			✔
ICDF visitor	Design [a]	Landfill, Treatment waste, Evap Pond	Varies	None	15[b]	3[g]	8	✔	✔	✔	✔

Table 3-1. (continued).

Exposure Scenario	EPC Source: Concentration Source	EPC Source: Inventory Source	Distance From Source (m)	Shielding	Duration (yrs)	Frequency (days/ year)	Time (hrs/ day)	Exposure Routes: Direct Radiation	Exposure Routes: Incidental Ingestion	Exposure Routes: Dermal Contact	Exposure Routes: Inhalation
General Public											
Highway 26 Rest Area visitor	WAC [f]	Landfill	[h]	[h]	[h]	[h]	[h]	✔			✔

a. Design inventory concentrations based on "INEEL CERCLA Disposal Facility Design Inventory" (EDF-ER-264).

b. 15 years is based on the anticipated operational design life of the landfill disposal cell.

c. 158 days per year is based on 144 days per year (i.e., 36 weeks per year at 4 days/week) plus 14 days per year (i.e., 14 weeks per year at 1 day/week).

d. 200 days per year is based on 50 weeks per year at 4 days/week.

e. 25 years is based on an assumed duration an individual remains employed in one position.

f. WAC concentrations based on *Waste Acceptance Criteria for ICDF Landfill* (DOE 2002).

g. One visit per year visiting for 1 day each at the landfill, treatment area, and evaporation pond.

h. Qualitatively evaluated based on scaling from the CFA office worker.

3.1.1 Radiation Worker II Exposure Scenarios

The following subsections describe the exposure scenarios associated with a Radiation Worker II. The location of the exposed individual with respect to the ICDF Complex is approximated in Figure 3-1. The scenarios discussed below are based on maximum exposure times, mitigation factors are not considered, and maximum constituent concentrations were used. As such, the exposure scenarios shall provide an upper bound to the realized conditions.

3.1.1.1 Landfill Bulldozer Operator. This exposure scenario assumes that the landfill bulldozer operator remains inside the bulldozer (1.5 m above the landfill surface) during the entire exposure duration, and has no contact with the landfill surface. The operator is shielded by 1.3 cm (0.5 in.) of iron from the bulldozer. The exposure duration for the landfill bulldozer operator scenario is 15 years (the operational design life of the landfill disposal cell). The operator is expected to work at the landfill for a total of 158 days per year; which is based on an exposure frequency as follows:

- Four days per week, 10 hours per day, for 36 weeks (March through November).

- One day per week, 10 hours per day, for the remaining 14 weeks of the year (November through February). Note, although is it unlikely that landfill operations will occur during the winter months, this additional exposure was included. It is anticipated that only treated waste will be transported to the ICDF landfill during the winter months.

The landfill bulldozer operator will potentially be exposed to landfill concentrations representative of the total design inventory as a result of direct radiation, incidental ingestion, dermal contact, and inhalation routes of exposure.

3.1.1.2 Landfill Laborer. This exposure scenario assumes that the landfill laborer remains in direct contact with the landfill surface (1 m above ground surface) during the entire 15-year exposure duration with no shielding. The exposure frequency and exposure time for this scenario is the same as that described for the landfill bulldozer operator scenario.

The landfill laborer will potentially be exposed to landfill concentrations representative of the total design inventory as a result of direct radiation, incidental ingestion, dermal contact, and inhalation routes of exposure.

3.1.1.3 Landfill Truck Driver. This exposure scenario assumes that the landfill truck driver remains inside the truck (1.5 m [5.0 ft]) above the landfill surface during the entire 15-year exposure duration, and has no contact with the landfill surface. The driver is shielded by 6.3 mm (0.25 in.) of iron from the truck and 0.2 m (6 in.) of clean fill on the haul road. The landfill truck driver is also exposed to landfill material approximately 4.6 m (15 ft) away with only 6.3 mm (0.25 in.) of shielding and the waste box approximately 0.9 m (3 ft) behind the truck and approximately 9.1 m (30 ft) long 12 m × 1 m box with only 1.3 mm (0.5 in.) of iron shielding. The exposure frequency and exposure time for this scenario is the same as that described for the landfill bulldozer operator scenario.

The landfill truck driver will potentially be exposed to landfill concentrations representative of the total design inventory as a result of direct radiation, incidental ingestion, dermal contact, and inhalation routes of exposure.

3.1.1.4 Treatment Unit Operator. This exposure scenario assumes that the treatment unit operator transfers waste from 4 × 4 × 8 ft unshielded wooden boxes to the waste treatment batch and following treatment transfers waste to a container prior to disposal. The treatment unit operator spends time in the vicinity of the waste container in a random fashion and makes the following assumptions on exposure time: 1% (6 minutes) of his time is spent 0.3 m from the waste container; 10% (1 hour) of his time 1.0 m from the container; 10% (1 hour) of his time 2.0 m from the container; and 70% (7 hours, 54 minutes) of his time 3.0 m from the container. This operation is anticipated to treat approximately 10 yd^3 of contaminated soil per day. The exposure duration for the treatment unit operator scenario is 15 years based on the operational design life of the landfill disposal cell. The operator is expected to work at the treatment facility 200 days per year for 10 hours each day.

The treatment unit operator will potentially be exposed to soil concentrations representative of the waste requiring treatment as a result of direct radiation incidental ingestion, dermal contact, and inhalation routes of exposure.

3.1.1.5 Evaporation Pond Operator. This exposure scenario assumes that the evaporation pond operator stands on a berm at the edge of the evaporation pond with two cells without shielding. At this location, the operator would be 2.0 m above and 2.0 m from the edge of the source of radiation during the entire 25-year exposure duration. The exposure duration for the evaporation pond operator scenario is 25 years based on the amount of time an individual remains employed at one position. The exposure frequency and exposure time for this scenario is 200 days per year for 2 hours each day.

The evaporation pond operator will potentially be exposed to leachate concentrations representative of evaporation pond contents as a result of direct radiation and inhalation routes of exposure.

3.1.2 General Employee Radiation Training Worker Exposure Scenarios

The following subsections describe the exposure scenarios associated with a general employee radiation training worker. The location of the exposed individual with respect to the ICDF Complex is approximated in Figure 3-1.

3.1.2.1 ICDF Office Worker. This exposure scenario assumes the ICDF office worker is a downwind receptor of the ICDF Complex. This exposure scenario assumes that the office worker will not go any closer to the ICDF Complex than the ICDF admin trailer (100 m away from the landfill and 63 m from the decon building) shielded by the landfill berm. The exposure duration for the ICDF office worker scenario is 15 years based on the operational design life of the landfill disposal cell. It is anticipated that the worker will be at the ICDF admin trailer 200 days per year for 10 hours each day.

The ICDF office worker will potentially be exposed to the landfill's and the treatment unit's total design inventory as a result of direct radiation and inhalation routes of exposure.

3.1.2.2 CFA Office Worker. This exposure scenario assumes the CFA office worker is a downwind receptor of the ICDF Complex. This exposure scenario assumes that the office worker will not go any closer to the ICDF Complex than the CFA (4,000 m away from the landfill) without shielding. The exposure duration for the CFA office worker scenario is 15 years based on the operational design life of the landfill disposal cell. It is anticipated that the worker will be at the CFA 200 days per year for 10 hours each day.

The CFA office worker will potentially be exposed to the landfill's total design inventory as a result of direct radiation and inhalation routes of exposure.

3.1.2.3 Delivery Driver. This exposure scenario assumes the delivery driver is a downwind receptor of the ICDF Complex. This exposure scenario assumes that the delivery driver will not go any closer to the ICDF Complex than the ICDF admin trailer (100 m from the landfill and 63 m from the decon building) shielded by the berm. The exposure duration for the delivery driver scenario is 15 years based on the operational design life of the landfill disposal cell. It is anticipated that the delivery driver visits will be restricted to the ICDF admin trailer, at an exposure frequency of 200 days per year for 1 hour each day.

The delivery driver will potentially be exposed to the ICDF landfill's and treatment unit's total design inventory as a result of direct radiation and inhalation routes of exposure.

3.1.2.4 INEEL Worker. This exposure scenario assumes that an INEEL employee will frequent the ICDF Complex to perform ground and power line maintenance in the areas between the ICDF landfill cells and the evaporation pond with two cells. It is anticipated that the INEEL employee will spend 50% of the time performing ground maintenance and 50% of the time performing power line maintenance (12 m above the surface) and the berms provide the only shielding. The exposure duration for the INEEL worker is 15 years based on the operational design life of the landfill disposal cell. It is anticipated that the INEEL worker will be at this exposure area for a total of 10 days per year for 8 hours each day.

The INEEL worker will potentially be exposed to the landfill's and evaporation pond's total design inventory as a result of direct radiation, incidental ingestion, dermal contact, and inhalation routes of exposure.

3.1.3 Member of the Public Entry Exposure Scenarios

The following subsections describe the exposure scenarios associated with a member of the public entry. The location of the exposed individual with respect to the ICDF Complex is approximated in Figure 3-1.

3.1.3.1 INEEL Visitor. This exposure scenario assumes that a visitor will frequent the areas outside the fence line (approximately 85 m) from the ICDF Complex with the berm providing the only shielding (15 to 30 m of berm width). The exposure duration for the INEEL visitor is 15 years based on the operational design life of the landfill disposal cell. It is anticipated that the INEEL visitor will be at this exposure area for a total of 10 days per year for 8 hours each day.

The INEEL visitor will potentially be exposed to soil concentrations representative of the landfill WAC as a result of direct radiation and inhalation routes of exposure.

3.1.3.2 ICDF Visitor. This exposure scenario assumes that a visitor will frequent the ICDF Complex 3 days per year over an exposure duration of 15 years. The visit will include 1 day each (8 hours per day) at the landfill, the evaporation pond with two cells, and the treatment area.

The ICDF visitor will be potentially exposed to constituent concentrations representative of the landfill (total design inventory), the treatment unit (CFA-04, CPP-92, CPP-98, and CPP-99), and the evaporation pond berm (modeled from evaporation pond leachate concentrations) as a result of direct radiation, incidental ingestion, dermal contact, and inhalation routes of exposure.

3.1.4 General Public Exposure Scenario

3.1.4.1 Highway 26 Rest Area Visitor. The Highway 26 Rest Area visitor scenario was scaled qualitatively based on the results of the CFA office worker scenario, which bounds any exposure that the Highway 26 Rest Area visitor may receive.

3.2 Calculation of Exposure Point Concentrations

EPCs for the ICDF Complex were derived from the ICDF Design Inventory of organic, inorganic, and radionuclide contaminants (EDF-ER-264). The inventory sources include the landfill, treatment area, and evaporation pond with two cells. The treatment area and evaporation pond include a subset of the constituents and associated concentrations defined in the design inventory. A summary of the sources is provided in Table 3-2, including a listing of the applicable exposure scenarios.

Table 3-2. Exposure point concentration source summary and applicable exposure scenario.

EPC Source	Applicable Exposure Scenario
Landfill Design Inventory	Landfill bulldozer operator, Landfill laborer, Landfill truck driver, ICDF office worker, CFA office worker, Delivery driver, INEEL worker, ICDF visitor
Landfill WAC	INEEL visitor, Highway 26 Rest Area visitor
Treatment Waste Design Inventory	Treatment unit operator, ICDF office worker, Delivery driver, ICDF visitor
Evaporation Pond Design Inventory	Evaporation pond operator, INEEL worker, ICDF visitor

The EPCs for the treatment area were derived from a subset of sites (CFA-04, CPP-92, CPP-98, and CPP-99) at the ICDF Complex that are considered "typical soils" at the treatment area. It is anticipated that these sites contain wastes that cannot be placed directly into the landfill and therefore are anticipated to require treatment at the treatment area prior to placement in the landfill. The design inventory from these four sites are equally represented and evaluated to determine the EPCs for the waste requiring treatment.

The EPCs for the evaporation pond were derived from the inventory anticipated to leach from the landfill "Leachate/Contaminant Reduction Time" (EDF-ER-274). The inventory of COPC was calculated based on the leachate concentrations. These concentrations were then modified to account for precipitation and the addition of makeup water.

The EPCs associated with the WAC are specific to the landfill (DOE-ID 2002). These EPCs are evaluated in cases where the general public may be involved.

Exposure scenarios evaluated that occur at a distance from the source (i.e., CFA office worker, ICDF office worker, delivery driver, and the INEEL worker), used the GXQ (a computer code) (WHC 1994) to estimate the amount of dilution in airborne radionuclide concentrations that would occur from the source to the receptor location. From this analysis, a dilution factor (DF) value was selected to conservatively adjust EPCs for the distance exposure areas. Equation (1) was used to adjust the EPCs for each of the identified exposure scenarios:

$$EPC_{Exposure\ Scenario} = EPC_{Landfill} \times DF \tag{1}$$

Where:

4,000 m (CFA office worker)	DF = 3.2E - 7
300 m (INEEL visitor)	DF = 1.00E - 4
100 m (ICDF office worker, delivery driver)	DF = 1.97E - 4
63 m (ICDF office worker, delivery driver)	DF = 4.76E - 4.

3.2.1 Radionuclide EPCs

A total of 210 radionuclides were identified as part of the design inventory. The radionuclide COPC selection process described in Section 3.5 was used to reduce this list to only those radionuclides expected to significantly contribute to receptor radiation exposures. These exposure point radionuclide concentrations are provided in Appendix A, Table A-1.

3.2.2 Nonradionuclide EPCs

A total of 121 organic and 39 inorganic constituents were identified as part of the design inventory. With the exception of those constituents that do not have appropriate surrogate toxicity factors (see Section 3.4.2), all organic and inorganic constituents were identified as COPCs and carried forward into the risk assessment. Table 3-3 lists the chemicals for which toxicity factors could not be identified. Since there are no identified toxicity factors, these chemicals were eliminated from further consideration.

Table 3-3. Chemicals eliminated from the risk assessment evaluation.

COPC	COPC	COPC
3-methyl butanal	Famphur	lead
4-bromophenyl-phenyl ether	2,6,10,15-tetra heptadecane	nitrate
4-chloro-3-methylphenol	isopropyl alcohol/2-propanol	nitrate/nitrite-N
4-chlorophenyl-phenyl ether	mesityl oxide	phosphorus
bis (2-chloroethoxy)methane	2,3,7-trimethyl octane	sulfate
1,1,3,4-tetrachlorobutane	o-toluene sulfonamide	sulfide
3,4-dimethyl decane	2,6-bis(1,1-dimethyl) phenol	terbium
diacetone alcohol	p-toluenesulfonamide	ytterbium
dimethyl disulfide	Tributylphosphate	zirconium
Eicosane	4,6-dimethyl-undecane	
ethyl cyanide	Chloride	

Lead concentrations in soil were compared to the EPA Region IX Preliminary Remediation Goal (PRG) of 750 mg/kg for the industrial scenario and lead concentrations in water were compared to the maximum contaminant level of 0.015 mg/L. The lead EPCs for the design inventory and the treatment unit were 57.7 mg/kg and 22.8 mg/kg, respectively, and the lead EPC for the evaporation pond leachate was 0.0004 mg/L. Lead EPCs in soil were less than the Region IX PRG of 750 mg/kg and the lead EPC in water was less than the MCL of 0.015 mg/L, therefore lead was not carried forward into the risk assessment.

The design inventory concentrations provided site mass in soil (in kilograms) for each individual COPC and also provided the total mass in soil (in kilograms) for all constituents identified in the design inventory (EDF-ER-264). Exposure point concentrations for each COPC were calculated using Equation (2):

$$EPC\left(\frac{mg}{kg}\right) = \frac{Total\ Mass\ (kg)}{Site\ Mass\ (kg)} \times 1 \times 10^{6}\left(\frac{mg}{kg}\right) \tag{2}$$

The evaporation pond modeled leachate concentrations (EDF-ER-274) were incorporated into the anticipated liquids volume to determine the associated concentrations. Appendix A, Table A-2 provides a summary of nonradionuclide EPCs for each exposure area evaluated.

3.3 Exposure Pathways and Assumptions

The exposure pathways evaluated for each exposure scenario were briefly described in Section 3.1. A description of the exposure pathways evaluated in this risk assessment is provided in Table 3-4.

Table 3-4. Exposure pathways evaluated for the ICDF.

Pathway	Description
Direct radiation	The direct radiation exposure route is evaluated for penetrating (gamma) radiation. Gamma radiation exposures are calculated with the MicroShield computer code.
Incidental ingestion	The incidental ingestion exposure pathway includes the ingestion of surface soils at a rate of 100 mg per day as shown in the *Exposure Factors Handbook* (EPA 1997a).
Dermal contact	The dermal contact exposure pathway is evaluated for nonradiological constituents only. A skin surface area of 3,300 cm^2 assumes the worker is wearing a short-sleeved shirt, long pants, and shoes. A soil adherence factor of 0.2 mg/cm^2 is assumed.
Inhalation	The inhalation exposure pathway includes inhalation of resuspended fugitive dust and volatile emissions from the identified exposure area. An inhalation rate of 0.02 m^3/min (28.8 m^3/day) is used for each identified receptor as shown in "Limiting Values of Radionuclide Intakes and Air Concentrations and Dose Conversion Factors for Inhalation, Submersion, and Ingestion" (EPA 1988). This inhalation rate is consistent with the inhalation rate given by ICRP-23 for light (working) activity of 20 liters/min for the adult reference male as shown in "Report on the Task Group on Reference Man" (ICRP 1975).
	The resuspension rate, or the soil-to-air particulate emission factor (PEF) is based on site-specific data obtained in *The Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1989* (DOE-ID 1990). This report indicates an annual average value of 40 $\mu g/m^3$ for total particulate matter.
	Nonradiological volatile organic compounds (VOCs) are defined as those chemicals with a molecular weight less than 200 grams/mole and have a Henry's Law Constant (HLC) greater than 10^{-5}. The volatilization factors for VOCs identified within the design inventory are calculated using the Jury Model as described in the EPA *Superfund Soil Screening Guidance: Users Guide* (EPA 1996) and are presented in Appendix B, Table B-2 (EPA 1996).

3.4 Methodology for Calculation of Risk Estimates

The methodology for the calculation of risk estimates is described in the following sections.

3.4.1 Equations for Calculating Nonradiological Risk Estimates

The equations for calculating nonradiological risk estimates involve Calculation of Intake. Exposure that is normalized over time and body weight is termed intake (expressed as milligrams of chemical per kilogram body weight per day [mg/kg-day]). The reasonable maximum exposure (RME) case is defined as the highest exposure that is reasonably expected to occur at the ICDF Complex. The intent of the RME scenario is to estimate a conservative exposure case that is still within the range of possibilities. Appendix B, Table B-1, presents the human exposure assumptions for soil pathways used in the risk assessment.

Equation (3) was used to estimate the chemical intake associated with the incidental ingestion of soil:

$$I = \frac{C_s \times CF \times IR_s \times EF \times ED}{BW \times AT \times 365\ days/year} \tag{3}$$

Where:

I = Intake (mg/kg body weight-day)

C_S = Chemical concentration in soil (mg/kg)

CF = Conversion factor (10^{-6} kg/mg)

IR_S = Ingestion rate (soil ingestion [mg/day])

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

BW = Adult body weight (kg)

AT = Averaging time (years).

Equation (4) was used to estimate the chemical intake associated with dermal contact with soil:

$$I = \frac{C_s \times CF \times EF \times ED \times ABS \times AF \times SA}{BW \times AT \times 365\ days/year} \tag{4}$$

Where:

I = Intake (mg/kg body weight-day)

C_S = Chemical concentration (mg/kg)

CF = Conversion factor (10^{-6} kg/mg)

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

BW = Adult body weight (kg)

AT = Averaging time (years)

ABS = Dermal absorption factor (%)

AF = Soil-to-skin adherence factor (mg/cm^2)

SA = Exposed skin surface area (cm^2/day).

Equation (5) was used to estimate the chemical intake associated with inhalation of particulate and volatile emissions from soil:

$$I = \frac{C_S \times IR_{INH} \times \left(\frac{1}{PEF} + \frac{1}{VF} \right) \times EF \times ED \times ET}{BW \times AT \times 365\ days/year} \tag{5}$$

Where:

I = Intake (mg/kg body weight-day)

C_S = Chemical concentration (mg/kg)

IR_{INH} = Inhalation rate (m^3/day)

PEF = Particulate emissions factor (m^3/kg)

VF = Volatilization factor (m^3/kg)

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

AT = Averaging time (years)

ET = Exposure time (hrs/day).

Equation (6) was used to estimate the chemical intake associated with the inhalation of volatile emissions from water:

$$I = \frac{C_a \times EF \times ED}{BW \times AT \times 365\ days / year} \tag{6}$$

Where:

I = Intake (mg/kg body weight-day)

C_a = Chemical concentration (mg/m^3)

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

BW = Adult body weight (kg)

AT = Averaging time (years).

Air concentrations were calculated in accordance with the EPA's *Air Emissions Models for Waste and Wastewater* document (EPA 1994) and are described in Appendix E. Emissions from standing water to air, mass transfer coefficient calculations, and calculation of ambient air concentrations are presented in Tables E-1, E-2, and E-3, respectively.

Equation (7) was used to calculate ELCR:

$$ELCR = CSF \times CDI \tag{7}$$

Where:

ELCR = Excess lifetime cancer risk

CSF = Cancer slope factor (risk per mg/kg-day)

CDI = Chronic daily intake (mg/kg-day).

Appendix B, Table B-2, provides a summary of cancer slope factors for each COPC.

Equation (8) was used to estimate the hazard index:

$$HI = \frac{CDI}{RfD} \tag{8}$$

Where:

HI = Hazard index

RfD = Reference dose (mg/kg-day)

CDI = Chronic daily intake (mg/kg-day).

3.4.2 Toxicity Factors

The primary source of toxicity values (i.e., CSFs, inhalation slope factors, oral reference doses, and inhalation reference doses) is the EPA's Integrated Risk Information System (IRIS) database. Available through the EPA National Center for Environmental Assessment, the IRIS is an electronic database, prepared and maintained by the EPA, that contains health risk and EPA regulatory information on specific chemicals (EPA 2000a).

If a toxicity value was not available from the IRIS, then Health Effects Assessment Summary Tables (HEAST) were used. The HEAST, provided by the EPA Office of Solid Waste and Emergency Response (EPA 1997b) are a compilation of toxicity values published in various health effects documents issued by EPA.

Appendix B, Table B-2, presents the toxicity values used to calculate risk estimates, which were obtained from IRIS, HEAST, or the U.S. EPA Region IX Preliminary Remediation Goal Table (EPA 2000b) on the EPA's web site at http://www.epa.gov/docs/region09/waste/sfund/prg/index.html.

When available, appropriate surrogate toxicity factors were used for detected chemicals without toxicity factors. The use of surrogate toxicity factors assumes the toxicity of structurally similar compounds is equivalent—an assumption that may result in an under or overestimate of risks at the ICDF Complex. Table 3-5 indicates the surrogate selected for each chemical.

Table 3-5. Surrogates used for detected chemicals.

Detected Chemical	Surrogate
3-nitroaniline and 4-nitroaniline	2-nitroaniline
2-nitrophenol	4-nitrophenol
acenaphthylene	acenaphthene
polychlorinated biphenyl (PCB) aroclor 1268	PCB aroclor 1260
benzo(g,h,i)perylene	pyrene

As calcium, magnesium, potassium, and sodium are chemicals considered essential nutrients necessary for human nutrition, risk estimates were not calculated for these constituents.

3.5 Selection of Radionuclide Contaminants of Concern

The list of radionuclide constituents that could potentially be present at the ICDF Complex is taken from the design inventory of the ICDF landfill (EDF-ER-264). COPCs are those radionuclides that should be carried through the risk quantification process. The following exclusionary criteria were then used to eliminate radionuclide constituents from this design inventory:

- Criterion 1. Radionuclides that are noble gasses (i.e., krypton, xenon, etc.) are assumed to have been liberated during excavation, and transport container loading/unloading operations. Exceptions to this rule include radon, which will be regenerated after placement in the disposal cell (ingrowth from parent radionuclides), and tritium, which will probably exist as tritiated water entrained in the soil.

- Criterion 2. Any radionuclide with a half-life value of 17 hours or less is assumed to have decayed to insignificant levels before worker exposure can occur. Exceptions to this rule include short-lived decay products of longer-lived parent radionuclides.

- Criterion 3. Any radionuclide whose reported concentration is less than 1×10^{-16} Ci/kg (<0.1 pCi/g) is assumed to be an insignificant contributor to either external or internal exposures. To verify that such radionuclides are in fact insignificant contributors, the radionuclide-specific slope factors published in the EPA's HEAST were applied to the listed concentration for a period of 25 years (the longest ICDF worker exposure period). Radionuclides whose combined risk values were less than 1.0×10^{-6} were considered to be insignificant contributors and eliminated from the list.

- Criterion 4. Any radionuclide, or its significant decay products, that is not listed in the MicroShield database was not considered in the assessment of direct radiation exposures. This includes those radionuclides whose half lives or abundance is too small to be considered (e.g., astitine-217, etc.). This criterion will not be applied to the ingestion and inhalation pathways.

- Criterion 5. Any radionuclide that does not have significant gamma or X-ray emissions (e.g., the so-called pure beta and/or alpha emitters) will be excluded from the direct radiation exposure assessment. However, such radionuclides will be considered in the inhalation and ingestion exposure assessments, unless they are eliminated through consideration of one or more of these criteria. Some radionuclides listed in the design inventory were identified as being gamma emitters, due to the presence of weak or low-intensity X-rays (e.g., lead X-rays). In some such instances, MicroShield will not include these radionuclides.

- Criterion 6. Any radionuclide that upon inspection contributes less than 1% of the total dose, so long as the aggregate of such radionuclide doses does not exceed 10% of the total dose as shown in the "Multi-Agency Radiation Survey and Site Investigation Manual" (DOE 2000).

Appendix C, Table C-1, summarizes the list of radiological contaminants from the design inventory list and presents the results of the COPC selection process. Screening results presented in Table C-1 indicate whether the radiological contaminant was included or excluded as a COPC.

An additional level of screening was performed using MicroShield to determine the relative contribution of each radionuclide for the external exposure pathway. The MicroShield infinite slab geometry was selected to represent the areal extent of a disposal cell. Notably, "infinite" in the context of MicroShield calculations refers to the amount of shielding represented by the source matrix itself. Consequently, run time for the code is significantly reduced, as compared to inputting a very large rectangular volume source. With this geometry, however, user input is limited to the thickness of the slab and the height of the dose point above the slab. The effect of source term thickness was evaluated for a wide range of gamma (photon) energies. Figure 3-2 illustrates the general effect for all input radionuclides.

Two general effects should be noted; 1) for thicknesses below approximately 0.3 to 0.4 m, the exposure rate increases with increasing thickness, and 2) the dose rate increases with increases in photon energy. As an example, 77% of the photon emissions from thallium-208 is 2,615 kiloelectron volts (keV), whereas 67% of the photon emissions from uranium-235 is 186 keV (a difference of more than 2,300 keV).

Figure 3-3 is a more precise representation of this effect for thallium-208. As shown, the thickness of the infinite slab becomes "infinite" itself at about 0.8 m, even for the most energetic photons evaluated. Consequently, a soil thickness of 1.0 m was selected to represent the disposal cell thickness. Although larger thickness values would have no effect on the calculated exposure rate, the code run-time would be increased.

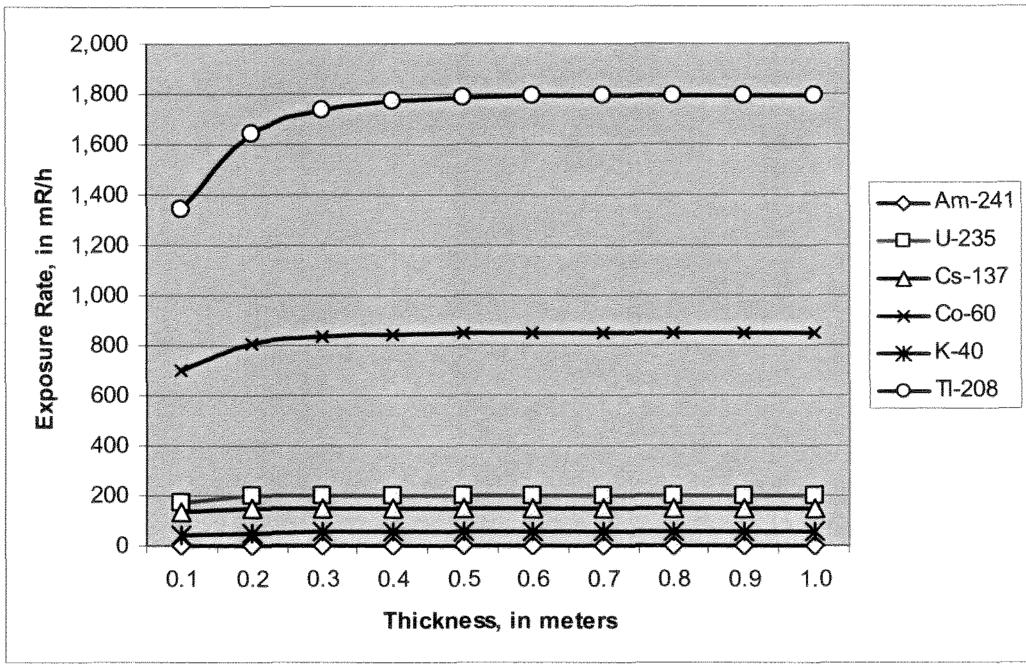


Figure 3-2. Effect of source thickness for various selected photon energies (radionuclides).

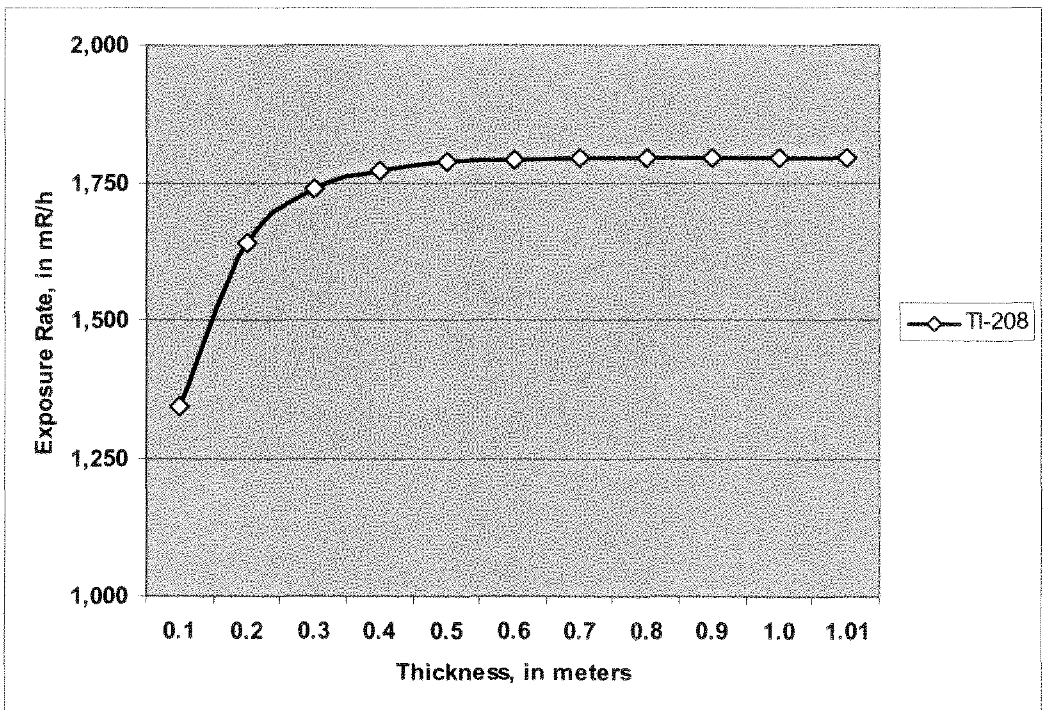


Figure 3-3. Effect of source thickness for highly energetic photons.

The MicroShield code is also sensitive to distances between the source and the dose point. Specifically, as the distance between the source and the dose point becomes very small, the point kernel used by MicroShield becomes very approximate. As stated in the MicroShield User's Manual for such conditions, "An even number of kernels will produce a different result than an odd number as the distance to the center of the kernel is a significant fraction of the distance from the kernel boundary to the dose point" (MicroShield 1998). To determine whether this effect was significant in this analysis, MicroShield runs were made for thallium-208 at dose point distances of 1.49 m, 1.50 m, and 1.51 m above source. The maximum variation produced was a negative 1.0 μR/h. This amount of variation is deemed acceptable for the purposes of this analysis.

Another MicroShield sensitivity assessed was the effect of the density of the source term on calculated exposure rates. Two competing forces must be considered; 1) as the density increases, the radionuclide concentration, hence the total number of emitted photons per unit volume, also increases, and 2) as the density increases, the amount of internal (self-) shielding also increases. Concrete was used as a surrogate for soil. The density was varied from 1.2 grams per cubic centimeter (g/cm^3) to 2.0 g/cm^3, in increments of 0.1 g/cm^3. The net effect is illustrated in Figure 3-4. As shown, the self-shielding effect is predominant. Consequently, a source matrix of concrete with a density of 1.2 g/cm^3 was selected for analysis of relative exposure contributions (radionuclide exclusion Criterion 6 above). This density choice will result in the most conservative estimate of radiation exposure for the range of densities evaluated. Receptor assessments are based on a soil density of 1.5 g/cm^3, which is representative of loose and disturbed soil, but less than the compacted soil density of 1.9 g/cm^3 to be achieved for final placement of the waste in the landfill.

In summary, the basic conditions used as MicroShield input parameters included the following:

- Infinite slab geometry, with a source thickness of 1.0 m.
- A dose point located 1.5 m above the top of the contaminated materials in the cell for the equipment operator, and 1.0 m above the top of the contaminated materials for the utility operator.
- Concrete at a density of 1.2 and 1.5 g/cm^3, as a surrogate for soil. Note that the density of 1.2 g/cm^3 was used for conservative radionuclide screening purposes, and the density of 1.5 g/cm^3 was used for exposure rate calculations in each of the exposure scenarios.
- Assumed buildup in the source term.
- Air at a density of 0.00122 g/cm^3 was used as the material between the source and the receptors.
- Assessment of the equipment operator's exposure, assumed that the bulldozer represents shielding equivalent to 0.5 in. of iron, at a density of 7.86 g/cm^3. No shielding other than air was used in the assessment of the utility worker walking on the surface of the landfill.
- The use of the MicroShield default photon energy library.
- The use of the MicroShield default photon energy grouping.
- The exclusion of photon energies below 15 keV from the analysis.

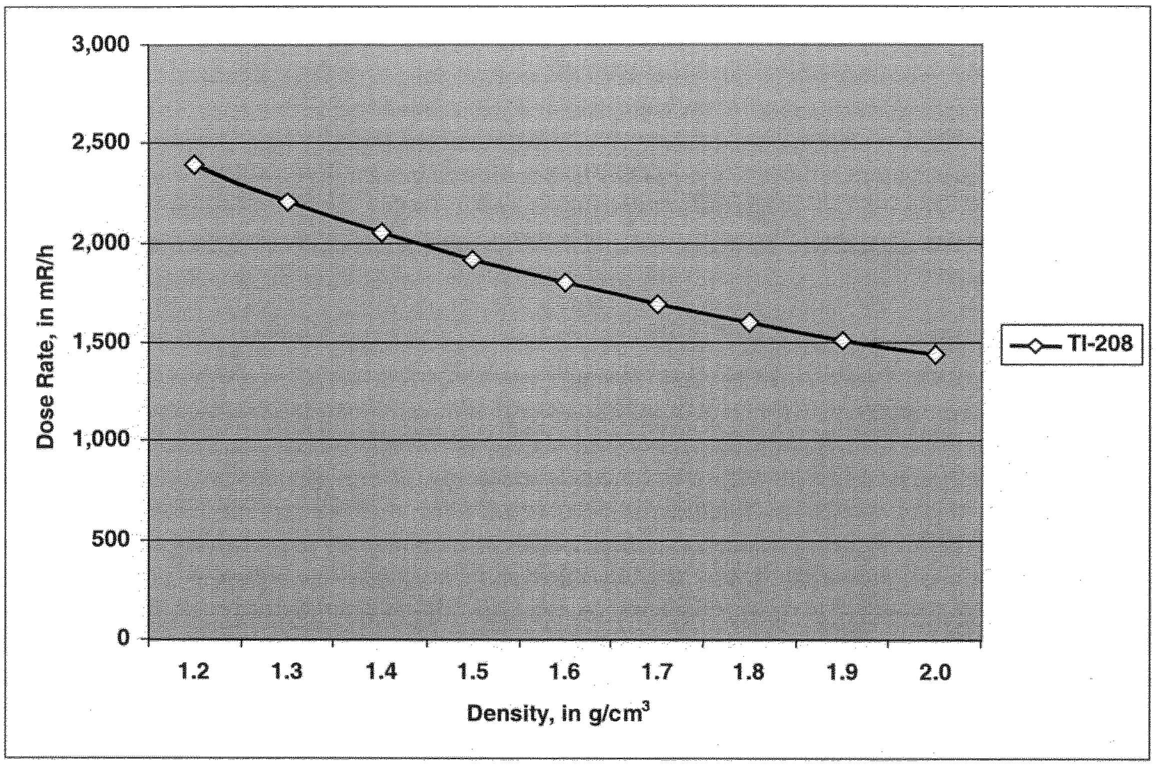


Figure 3-4. Effect of density on exposure rate.

The screening process described in the foregoing is illustrated in Appendix C, Tables C-1 and C-2. The results of the screening process for each of the three facilities assessed (landfill, treatment area, and evaporation pond with two cells) are presented in Appendix A, Table A-1. The radionuclides presented in Appendix A, Table A-1, and the associated EPC were then used to calculate receptor radiation exposures in Section 4.

4. RADIOLOGICAL ANALYSIS RESULTS

This section provides the results of the radiological analysis.

4.1 Dose Estimate Results for Landfill Laborer Exposure Scenarios

Three scenarios are considered for evaluating exposure to the landfill laborers and include: 1) a landfill bulldozer operator, 2) a landfill laborer (walking on landfill cell surface), and 3) a landfill truck driver.

4.1.1 External Radiation Exposure

The following assumptions were the basis of this evaluation:

- Landfill bulldozer operator: The bulldozer constitutes a shielding equivalent to 1.3 cm (0.5 in.) of iron between the source and the bulldozer operator. Consequently, a 0.5-in. iron shield will be located adjacent to the dose point. The distance from the ground surface to the bulldozer operator is 1.5 m (~5 ft).

- Landfill laborer (walking on landfill cell surface): The distance from the ground surface to an individual walking on the surface of the disposal cell is 1.0 m (~3.3 ft). No shielding was used in the assessment of external radiation exposure to the landfill laborer.

- Landfill truck driver: The truck constitutes a shielding equivalent to 0.006 m (0.25 in.) of iron from the truck and 0.2 m (6 in.) of clean fill on the haul road. The truck driver is also exposed to landfill material approximately 4.6 m (15 ft) away with only 6.3 mm (0.25 in.) of shielding, and the waste box approximately 0.9 m (3 ft) behind the truck. The waste box is a 9.1-m- (30-ft)-long, 12 m^3 volume box with only 13 mm (0.5 in.) of iron shielding.

Each radionuclide that passed the COPC screening process described above, and that emits significant photons, was evaluated for the concentrations provided in Appendix C, Table C-1 using a concrete density of 1.2 g/cm^3. The results of this evaluation are shown in Appendix C, Table C-2. Wherever the radionuclide did not have significant photon emissions, or wherever the radionuclide was not contained in the MicroShield default library of radionuclides, "NA" was entered into the table. Significantly, only a few of the radionuclides COPCs identified contribute substantially to the total radiation exposure. The primary contributors to total radiation include the following:

- Cobalt-60: 2.67%

- Cesium-137: 60.65%

- Europium-152: 16.81%

- Europium-154: 16.21%

- Europium-155: 3.48%.

In their aggregate, the above-listed radionuclides represent 99.82% of the total direct radiation exposure. Consequently, all direct exposure assessments will be limited to these radionuclides, in accordance with Criterion 6.

Exposure rates were calculated for the landfill laborer scenarios for each of the radionuclides COPCs identified in the screening process, as shown in Table 4-1.

Table 4-1. Landfill worker exposure rates.

	External Exposure Rates, in mR/h		
Radionuclide	Landfill Bulldozer Operator	Landfill Laborer	Landfill Truck Driver
Cobalt-60	8.50E - 02	2.67E - 01	1.33E - 01
Cesium-137	1.41E + 00	6.09E + 00	3.16E + 00
Europium-152	6.00E - 01	1.36E + 00	4.10E - 01
Europium-154	6.23E - 01	1.37E + 00	4.34E - 01
Europium-155	9.00E - 05	4.30E - 03	2.19E - 04
Totals	2.72E + 00	9.09E + 00	4.13E + 00

Annual exposure for the worker scenarios is calculated as the product of the total exposure rates shown in Table 4-1, exposure time (hours per day worked), and exposure frequency (days per year worked) as shown in Equations (9), (10), and (11). See Section 3 for exposure assumptions.

$$\begin{aligned}\text{Landfill Bulldozer Operator Dose} &= 2.72\ \text{mR/h} \times 10\ \text{h/d} \times 158\ \text{d/yr} \\ &= 4{,}298\ \text{mR/yr} \\ &= 4.3\ \text{R/yr}\end{aligned} \tag{9}$$

$$\begin{aligned}\text{Landfill Laborer Dose} &= 9.09\ \text{mR/h} \times 10\ \text{h/d} \times 158\ \text{d/yr} \\ &= 14{,}362\ \text{mR/yr} \\ &= 14.4\ \text{R/yr}\end{aligned} \tag{10}$$

$$\begin{aligned}\text{Landfill Truck Driver Dose} &= 4.13\ \text{mR/h} \times 10\ \text{h/d} \times 158\ \text{d/yr} \\ &= 6{,}525\ \text{mR/yr} \\ &= 6.5\ \text{R/yr}\end{aligned} \tag{11}$$

4.1.2 Internal Radiation Exposure

The same approach used for evaluation of external radiation exposures was taken to evaluate significant radionuclide contributors to the dose rate resulting from inhalation of resuspended soil. Appendix C, Table C-3 presents the results of this evaluation.

As in the external exposure evaluation above, only a few radionuclides contribute significantly to the internal dose due to inhalation and include the following:

- Strontium-/yttrium-90: 12.66%
- Plutonium-238: 73.37%

- Plutonium-239: 2.44%

- Americium-241: 8.74%.

In their aggregate, the above-listed radionuclides represent 97.91% of the total radiation dose resulting from inhalation of contaminated soil. Consequently, all inhalation dose assessments will be limited to these radionuclides, in accordance with Criterion 6.

Appendix C, Table C-4, is a similar evaluation for internal dose resulting from ingestion of the contaminated soil. As in the inhalation exposure evaluation above, only a few radionuclides contribute significantly to the internal dose rate resulting from ingestion of contaminated soil and include the following:

- Strontium-90/yttrium-90: 58.03%

- Cesium-137: 18.53%

- Plutonium-238: 19.66%

- Americium-241: 2.26%.

In their aggregate, the above-listed radionuclides represent 98.48% of the total radiation dose resulting from ingestion. Consequently, all ingestion dose assessments will be limited to these radionuclides, in accordance with Criterion 6.

The internal committed effective dose equivalent (CEDE) resulting from inhalation and incidental ingestion of contaminated soil is the same for the landfill laborer scenarios. This is because the pathways are independent of the shielding and height considerations used for the external radiation pathway. As such, the pathways are calculated in the same manner, as illustrated by Equation (12).

$$CEDE_i = (C_i \times U_j \times 2{,}370)/ALI_i \times 5{,}000 \qquad (12)$$

Where:

C_i = Concentration of the i^{th} radionuclide, in $\mu Ci/cm^3$ for inhalation, and $\mu Ci/g$ for ingestion

$\mu Ci/cm^3$ = $Ci/kg \times 10^6\ \mu Ci/Ci \times 10^{-9}\ kg/\mu g \times 10^{-6}\ m^3/cm^3 \times 40\ \mu g/m^3$

$\mu\ Ci/g$ = $Ci/kg \times 10^6\ \mu Ci/Ci \times 10^{-3}\ kg/g$

U_j = Uptake rate for the j^{th} pathway. $1.0 \times 10^7\ cm^3/d$ for inhalation, and 50 mg/d for ingestion.

2,370 = Days of exposure duration

= 158 d/yr

ALI_I = Annual limit on intake for the i^{th} radionuclide, in μCi.

5,000 = CEDE per ALI_i, in mrem/y.

Table 4-2 provides a summary of the TEDE for each of the COPCs.

Table 4-2. Internal annual CEDE for the landfill laborer scenarios.

Radionuclide	Inhalation Exposure (mrem/yr CEDE)	Ingestion Exposure (mrem/yr CEDE)	Total Internal Exposure (mrem/yr TEDE)
Strontium-90	2.17E + 00	6.02E + 01	6.24E + 01
Cesium-137	4.63E – 02	1.93E + 01	1.93E + 01
Plutonium-238	1.26E + 01	2.05E + 01	3.31E + 01
Plutonium-239	4.21E – 01	6.58E - 01	1.08E + 00
Americium-241	1.51E + 00	2.35E + 00	3.86E + 00
Totals	1.68E + 01	1.03E + 02	1.19E + 02

The CEDE value of 68 mrem (0.068 rem) is added to the external exposure for each landfill laborer to determine the TEDE, as shown in Equations (13), (14), and (15). The 1.0 R is equivalent to 1.0 rem for the photon energies emitted by the identified radionuclides of concern.

$$\text{Landfill bulldozer operator TEDE} = 4.3\ \text{R/yr} + 0.119\ \text{rem/y} = 4.4\ \text{rem/yr} \tag{13}$$

$$\text{Landfill laborer TEDE} = 14.4\ \text{R/yr} + 0.119\ \text{rem} = 14.5\ \text{rem/yr} \tag{14}$$

$$\text{Landfill truck driver TEDE} = 6.5\ \text{R/yr} + 0.119\ \text{rem} = 6.6\ \text{rem/yr} \tag{15}$$

The TEDE for the landfill bulldozer operator (4.4 rem/year) is less than the radiation dose limit of 5 rem/year identified for radiation workers. The TEDE for the landfill laborer (walking on the landfill surface) and the landfill truck driver exceed the radiation dose limit of 5 rem/year.

It is important to note that the TEDE values calculated for the landfill laborer are based on unmitigated risk. In no event will radiation workers be allowed to exceed the regulatory limit of 5 rem/year for occupational exposures. Section 6 of this document summarizes the approach for mitigating radiation risk at the INEEL.

4.2 Radiation Exposure Estimates for the ICDF Landfill Visitor

Because visitors to the landfill will be limited to uncontaminated locations exterior to the waste soil emplacements, a different MicroShield geometry was used to predict the exposure rate to which the visitor is subjected. As indicated in the foregoing, it is assumed that a visitor will be located such that the MicroShield dose point is 2 m back from the edge of the contaminated soil and 2 m above the contaminated soil. The radionuclide EPCs identified for the landfill laborer scenarios were used for the visitor scenario, and the same incidental ingestion and inhalation rate assumptions used for the landfill laborer scenarios were used for the visitor scenario. The visitor exposure duration at the landfill is limited to 8 hours/day, 1 day/year.

As MicroShield does not allow the user to input negative dose point coordinate values (e.g., a-2 m as the offset from the edge of a rectangular volume), an effective air gap of 2.828 m was used (e.g., the effective air gap = the square root of the sum of the square sides "a" and "b" shown in Figure 4-1) to approximate the intended air gap.

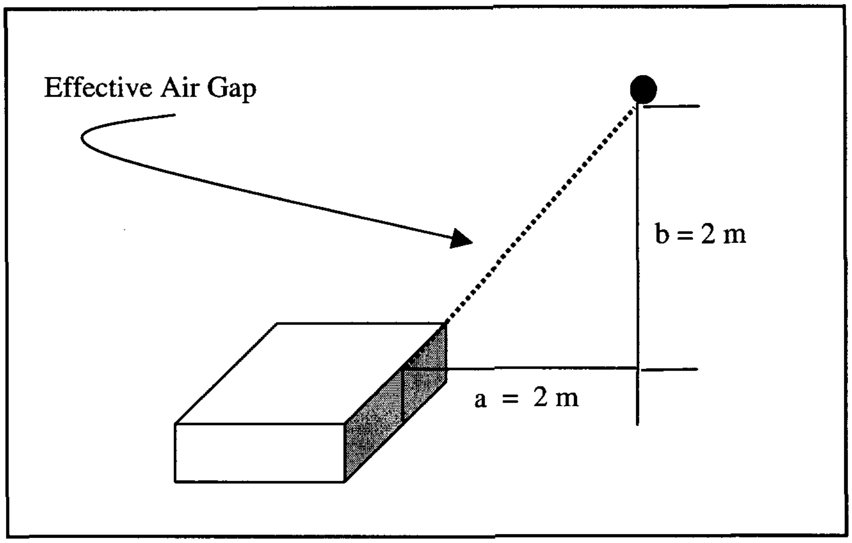


Figure 4-1. Effective air gap.

Rather than an infinite slab geometry, which would place the dose point over the center of the slab, a 10 m × 10 m rectangular volume geometry was used to approximate the infinite slab. The rectangular volume geometry allows placement of the dose point at the edge of the source, rather than over the center. The 10 m × 10 m rectangular volume has been shown to produce a conservatively equivalent result, when compared to the infinite slab geometry.

Equation (12) was used to calculate internal dose (effective dose equivalent [EDE]) resulting from the inhalation and ingestion pathways. Table 4-3 summarizes the results for each pathway for a visitor to the landfill.

Table 4-3. Landfill visitor radiation exposures.

Radionuclide	External Exposure (mR/y EDE)	Inhalation Exposure (mrem/y CEDE)	Ingestion Exposure (mrem/y CEDE)	Total Dose (mrem/y TEDE)
Cobalt-60	1.36E + 00	1.24E - 05	4.83E - 04	1.36E + 00
Strontium- 90	0.00E + 00	1.10E - 02	3.81E - 01	3.92E - 01
Cesium-137	3.65E + 01	2.35E - 04	1.22E - 01	3.66E + 01
Europium-152	2.85E + 00	9.29E - 05	6.05E - 04	2.85E + 00
Europium-154	2.92E + 00	7.88E - 05	8.20E - 04	2.92E + 00
Europium-155	1.03E - 02	3.76E - 06	2.21E – 05	1.03E - 02
Plutonium-238	0.00E + 00	6.40E - 02	1.30E - 01	1.94E - 01
Plutonium-239	0.00E + 00	2.13E - 03	4.16E - 03	6.30E - 03
Americium-241	0.00E + 00	7.62E - 03	1.49E - 02	2.25E - 02
Totals	4.36E + 01	8.52E - 02	6.54E - 01	4.44E + 01

The TEDE for the landfill visitor (0.040 rem/year) exceeds the total radiation dose limit of 0.015 rem/year identified for nonradiation workers and members of the public.

It is important to note that the TEDE values calculated for the landfill visitor are based on unmitigated risk. In no event will visitors be allowed to exceed the regulatory limit of 0.015 rem/year. Section 6 of this document summarizes the approach for mitigating radiation risk at the INEEL.

4.3 Dose Estimates for the Evaporation Pond Operator and Visitor

The ICDF evaporation pond inventory of radionuclides is described in Section 3.1.4. These radionuclides were screened in accordance with the six elimination screening criteria (Section 3.5). The radionuclides identified during the screening process include hydrogen-3, iodine-129, and technicium-99.

MicroShield was used to evaluate the exposure rate for the evaporation pond radionuclide COPCs. The exposure scenario identifies a receptor standing on a berm at the edge of the evaporation pond, with no accommodation for any shielding. This places the receptor at 2.0 m removed from the edge of the source, and 2.0 m above the source. Similar to that of the landfill, the "source" is assumed to be 1.0 m in thickness. Given the different receptor location, a different MicroShield geometry (rectangular volume) was used. This geometry and receptor location are valid for both the evaporation pond operator and evaporation pond visitor.

Exposures to airborne concentrations were calculated for hydrogen-3, iodine-129, and technicium-99. It was assumed that all of these radionuclides become airborne through evaporation. An evaporation rate of 25.9 in. per year (EDF-ER-274) was assumed for these calculations. A nominal "residence time" of 1 hour for radionuclides in the mixing zone was assumed. This is comparable and slightly greater than basing calculations on complete saturation of the mixing space air. The concentration in the evaporated water was conservatively set equal to the concentration in the evaporation pond liquids.

A summary of the TEDE for each of the COPCs identified for the evaporation pond operator is presented in Table 4-4.

Table 4-4. Evaporation pond operator exposure estimates.

Radionuclide	External Exposure (mR/y EDE)	Inhalation Exposure (mrem/y CEDE)	Total Exposure (mrem/y TEDE)
H-3	0.00E + 00	1.02E - 02	1.02E - 02
Tc-99	4.16E - 08	1.29E - 01	1.29E + 01
I-129	2.13E - 03	6.27E - 00	6.27E + 00
Totals	2.13E - 03	6.41E + 00	1.92 E + 01

The TEDE for the evaporation pond operator (0.019 rem/year) is less than the radiation dose limit of 5 rem/year identified for radiation workers. Doses to the evaporation pond visitor were calculated in the same manner as that used for the evaporation pond operator, with the exception that the exposure duration was shortened to one 8-hour day per year, as illustrated in Table 4-5.

Table 4-5. Evaporation pond visitor exposure estimates.

Radionuclide	External Exposure (mR/y EDE)	Inhalation Exposure (mrem/y CEDE)	Total Exposure (mrem/y TEDE)
H-3	0.00E + 00	2.04E - 04	2.04E - 04
Tc-99	8.32E - 10	2.57E - 01	2.57E - 01
I-129	4.27E - 05	1.25E - 01	1.25E - 01
Totals	4.27E - 05	3.82E - 01	3.83E - 01

The TEDE for the evaporation pond visitor (<0.001 rem/year) is less than the radiation dose limit of 0.015 rem/year identified for nonradiation workers and escorted public receptors.

4.4 Dose Estimates for the Treatment Unit Operator and Visitor

The following assumptions were used to estimate the treatment unit operator's total dose:

1. Incoming waste containers are wooden boxes measuring $4 \times 4 \times 8$ ft.

2. The waste container contents are represented by the average concentration of soil removed from CFA-04, CPP-92, CPP-98, and CPP-99. The design inventory supplied the values used to compute the average.

3. The treatment unit operator spends time in the vicinity of the waste container based on assumed worker activities. This variability is represented by the following assumptions during a given day:

   a. 6 minutes (1%) of the operator's time is spent at 1.0 ft (0.3 m) from the waste container

   b. 1 hour (10%) of the operator's time is spent at 1.0 m from the waste container

   c. 1 hour (10%) of the operator's time is spent at 2.0 m from the waste container

   d. 7 hours and 54 minutes (79%) of the operator's time is spent at 3.0 m from the container.

4. MicroShield cases were run for each of these distances for each radionuclide remaining after the elimination screening process.

5. Radiation doses resulting from inhalation and ingestion were not considered in accordance with the assumptions given in Section 3.

The radionuclide screening process eliminated all but cesium-137 and potassium-40, which account for 99.11% of the gamma exposure rate. Consequently, only cesium-137 and potassium-40 will be used to estimate the treatment unit operator exposure scenario.

MicroShield was used to calculate the cesium-137 and potassium-40 exposure rates at 1.0 ft (0.31 m), 1 m, 2 m, and 3 m from the $4 \times$ ft $\times$ 8 ft unshielded box. The resulting exposure rates were then used to calculate the total annual exposure, using the stay times shown above. The results of these calculations are shown in Table 4-6.

Table 4-6. Treatment unit operator annual exposure.

Distance from Waste Container (m)	Cesium-137 Exposure Rate (mR/h)	Potassium-40 Exposure Rate (mR/h)	Total Exposure Rate (mR/h)	Fraction of Time Spent at Distance	Operator Annual Exposure (mR/y)
0.3	1.27E - 01	1.46E - 03	1.26E - 01	0.01	2.53E + 00
1	4.77E - 02	5.55E - 04	4.83E - 02	0.10	9.66E + 00
2	1.80E - 02	2.12E - 04	1.82E - 02	0.10	3.64E + 00
3	9.07E - 03	1.07E - 04	9.18E - 03	0.79	1.45E + 01
Totals					3.03E + 01

A visitor to the treatment unit is assumed to be prohibited from access any closer than 3 m from the waste container. Consequently, the total exposure rate at 3 m from Table 4-6, 0.009 mR/h was used to calculate the annual EDE for the visitor, as shown in Equation (16).

$$EDE = 0.009 \text{ mR/h} \times 8 \text{ h/y} = 0.1 \text{ mR/yr} \quad (16)$$

The radionuclide elimination screening process for internal radiation doses resulted in the radionuclides shown in Table 4-7.

Table 4-7. Treatment unit operator annual TEDE.

Radionuclide	External Exposure (mR/y EDE)	Inhalation Exposure (mrem/y CEDE)	Ingestion Exposure (mrem/y CEDE)	Total Exposure (mrem/y TEDE)
Am-241	0.00E + 00	1.01E - 01	1.58E - 01	2.60E - 01
Cs-137	3.00E + 01	1.03E - 03	4.30E - 01	3.04E + 01
K-40	3.52E – 01	2.12E - 05	1.76E - 01	5.29E - 01
Pu-238	0.00E + 00	1.05E - 03	1.70E + 00	2.75E + 00
Ra-226	0.00E + 00	1.25E - 03	7.82E - 02	7.94E - 02
Sr-90	0.00E + 00	4.83E - 02	1.34E + 00	1.39E + 00
U-238	0.00E + 00	5.01E - 02	4.18E - 02	9.12E - 02
Totals	3.03E + 01	1.25E + 00	3.93E + 00	3.55E + 01

The TEDE for the treatment unit operator (0.04 rem/year) is less than the radiation dose limit of 5 rem/year identified for radiation workers. Visitor internals dose resulting from inhalation and ingestion were calculated using the same radionuclides and radionuclide concentrations as were used for the treatment unit operator calculations. The visitor exposure duration of 8 hours per year was used to calculate the annual CEDE, as illustrated in Table 4-8.

Table 4-8. Treatment area visitor annual TEDE.

Radionuclide	External Exposure (mR/y EDE)	Inhalation Exposure (mrem/y CEDE)	Ingestion Exposure (mrem/y CEDE)	Total Exposure (mrem/y TEDE)
Am-241	0.00E + 00	4.06E - 04	7.02E - 04	1.20E – 03
Cs-137	7.26E - 02	4.13E - 06	2.15E - 03	7.47E – 02
K-40	8.59E - 04	8.46E - 08	8.82E - 04	1.74E - 03
Pu-238	0.00E + 00	4.20E - 03	8.51E - 03	1.28E - 02
Ra-226	0.00E + 00	5.00E - 06	3.91E - 04	3.96E - 04
Sr-90	0.00E + 00	1.93E - 04	6.71E - 03	6.90E - 03
U-238	0.00E + 00	2.01E - 04	2.09E - 04	4.09E - 04
Totals	7.35E - 02	5.01E - 03	1.96E - 02	9.81E - 02

The TEDE for the treatment area visitor (<0.001 rem/year) is less than the radiation dose limit of 0.015 rem/year identified for nonradiation workers and escorted public receptors.

4.5 Dose Estimates for the CFA Office Worker

The office worker is assumed to be located at the CFA, 2.5 miles (~4,000 m) from the ICDF Complex. The radionuclides identified as COPCs for the landfill laborer scenario were also used to evaluate the external radiation exposure and inhalation CEDE for the CFA office worker. Exposure rates and the annual EDE for the CFA office worker are presented in Table 4-9.

The radionuclides COPCs used in the landfill laborer's internal dose assessment were used in the assessment of internal dose resulting from inhalation of contaminated soil originating at the landfill. A GXQ computer code evaluation was performed to determine the amount of dilution in the airborne concentrations of radionuclides at the landfill that would occur by the time the airborne-contaminated soil reached the CFA office building. The resultant DF was approximately 3.2×10^{-7}. This DF value was used to evaluate the radionuclides shown in Table 4-9.

Table 4-9. CFA office worker TEDE.

Radionuclide	External Exposure (mrem/y EDE)	Inhalation Exposure (mrem/y CEDE)	Total Exposure (mrem/y TEDE)
Cobalt-60	2.68E - 11	9.81E - 10	1.01 - 09
Strontium-90	0.00E + 00	8.70E - 07	8.70E - 07
Cesium-137	1.53E - 14	1.86E - 08	1.86E - 08
Europium-152	8.61E - 09	7.36E - 09	1.59E - 08
Europium-154	1.43E - 08	6.24E - 09	2.05E - 08
Europium-155	1.08E - 30	2.98E - 10	2.98E - 10
Plutonium-238	0.00E + 00	5.07E - 06	5.07E - 06
Plutonium-239	0.00E + 00	1.69E - 07	1.69E - 07
Americium-241	0.00E + 00	6.04E - 07	6.04E - 07
Totals	2.29E - 08	6.75E - 06	6.77E - 06

The TEDE for the CFA office worker (<0.001 rem/year) is less than the radiation dose limit of 0.1 rem/year identified for nonradiation workers and escorted public receptors.

4.6 Dose Estimates for the Delivery Driver

Radionuclide EPCs used for the ICDF landfill and treatment area were used for the delivery driver scenario. The frequency of the delivery driver's presence at the ICDF Complex was assumed to be 1 hour per day, 200 days per year. The delivery driver will be limited to the admin trailer located in the ICDF. As a consequence, the delivery driver will not be any closer to the landfill than 100 m and 63 m to the decon building. This distance is used to estimate the direct radiation exposure and the airborne concentrations originating at the landfill and decon building. The GXQ computer code (WHC 1994) was used to provide values for calculation of a DF at this distance. Table 4-10 illustrates the results of these calculations.

Table 4-10. Delivery driver radiation exposures.

Radionuclide	External Exposure (mR/y EDE)	Inhalation Exposure (mrem/y CEDE)	Total Dose (mrem/y TEDE)
Cobalt-60	2.84E - 22	6.10E - 08	6.10E - 08
Strontium- 90	0.00E + 00	5.64E - 05	5.64E - 05
Cesium-137	3.76E - 03	1.20E - 06	3.76E - 03
Europium-152	1.70E - 21	4.58E - 07	4.58E - 07
Europium-154	1.07E - 21	3.88E - 07	3.88E - 07
Europium-155	7.92E - 24	1.85E - 08	1.85E - 08
Plutonium-238	0.00E + 00	3.65E - 04	3.65E - 04
Plutonium-239	0.00E + 00	1.05E - 05	1.05E - 05
Americium-241	0.00E + 00	4.24E - 05	4.24E - 05
Totals	3.82E - 03	4.79E - 04	4.30E - 03

The TEDE for the delivery driver (<0.001 rem/year) is less than the radiation dose limit of 0.1 rem/year identified for nonradiation workers and escorted public visitors.

4.7 Dose Estimates for the ICDF Office Worker

The ICDF office worker is similar to the delivery driver exposure scenario with the exception that the frequency at the ICDF Complex was assumed to be 10 hours per day, 200 days per year. Table 4-11 illustrates the results of these calculations.

Table 4-11. ICDF office worker radiation exposures.

Radionuclide	External Exposure (mR/y EDE)	Inhalation Exposure (mrem/y CEDE)	Total Dose (mrem/y TEDE)
Cobalt-60	2.84E - 21	6.10E - 07	6.10E - 07
Strontium- 90	0.00E + 00	5.64E - 04	5.64E - 04
Cesium-137	3.76E - 02	1.20E - 05	3.76E - 02
Europium-152	1.7E - 20	4.58E - 06	4.58E - 06
Europium-154	1.7E - 20	3.88E - 06	3.88E - 06

Table 4-11. (continued).

Radionuclide	External Exposure (mR/y EDE)	Inhalation Exposure (mrem/y CEDE)	Total Dose (mrem/y TEDE)
Europium-155	7.92E - 23	1.85E - 07	1.85E - 07
Plutonium-238	0.00E + 00	3.65E - 03	3.65E - 03
Plutonium-239	0.00E + 00	1.05E - 04	1.05E - 04
Americium-241	0.00E + 00	4.24E - 04	4.24E - 04
Totals	3.38E - 02	4.79E - 03	4.30E - 02

The TEDE for the ICDF office worker (<0.001 rem/year) is less than the radiation dose limit of 0.1 rem/year identified for nonradiation workers and escorted public visitors.

4.8 Dose Estimates for the INEEL Worker

Radionuclide EPCs used for the ICDF landfill and evaporation pond operators were used for the INEEL worker scenario. It is assumed that the INEEL worker is conducting power management activities and is located between the landfill and the evaporation pond with two cells. The INEEL worker spends 50% of the time on the power pole with the remaining time on the surface. The frequency of the INEEL worker's presence at the ICDF Complex was assumed to be 8 hours per day, 10 days per year, for 15 years.

It is assumed that the power pole is approximately 12 m (40 ft) above the ground surface. The distance to the evaporation pond source term is approximately 45 m and the distance to the landfill source term is approximately 75 m. This distance is used to estimate the direct radiation exposure and the airborne concentrations originating at the ICDF Complex landfill and treatment area. The GXQ computer code was used to provide values for calculation of a DF at this distance. Tables 4-12 and 4-13 illustrate the results of these calculations for the evaporation pond and landfill, respectively. Table 4-14 provides a cumulative summary.

Table 4-12. INEEL worker radiation exposures from evaporation pond.

Radionuclide	External Exposure (mR/y EDE)	Inhalation Exposure (mrem/y CEDE)	Total Exposure (mrem/y TEDE)
Worker On Pole			
H-3	0.00E + 00	7.28E - 07	7.28E - 07
Tc-99	4.36E - 10	9.17E - 04	9.17E - 04
I-129	5.73E - 06	4.47E - 04	4.53E - 04
Worker On Ground			
H-3	0.00E + 00	7.28E - 07	7.28E - 07
Tc-99	2.67E - 29	9.17E - 04	9.17E - 04
I-129	1.33E - 26	4.47E - 04	4.47E - 04
Totals	5.73E - 06	2.73E - 03	2.74E - 03

Table 4-13. INEEL worker radiation exposures from landfill.

Radionuclide	External Exposure (mR/y EDE)	Inhalation Exposure (mrem/y CEDE)	Total Dose (mrem/y TEDE)
Worker on Pole			
Cobalt-60	2.67E - 01	4.42E - 08	2.67E - 01
Strontium- 90	0.00E + 00	3.92E - 05	3.92E - 05
Cesium-137	6.52E + 00	8.37E - 07	6.52E + 00
Europium-152	5.35E - 01	3.32E - 07	5.35E - 01
Europium-154	5.61E - 01	2.81E - 07	5.61E - 01
Europium-155	9.00E - 04	1.34E - 08	9.00E - 04
Plutonium-238	0.00E + 00	2.28E - 04	2.28E - 04
Plutonium-239	0.00E + 00	7.60E - 06	7.60E - 06
Americium-241	0.00E + 00	2.72E - 05	2.72E - 05
Worker on Ground			
Cobalt-60	1.27E - 22	4.42E - 08	4.42E - 08
Strontium- 90	0.00E + 00	3.92E - 05	3.92E - 05
Cesium-137	1.37E - 20	8.37E - 07	8.37E - 07
Europium-152	7.57E - 21	3.32E - 07	3.32E - 07
Europium-154	4.78E - 22	2.81E - 07	2.81E - 07
Europium-155	3.52E - 24	1.34E - 08	1.34E - 08
Plutonium-238	0.00E + 00	2.28E - 04	2.28E - 04
Plutonium-239	0.00E + 00	7.60E - 06	7.60E - 06
Americium-241	0.00E + 00	2.72E - 05	2.72E - 05
Totals	7.89E + 00	6.08E - 04	7.89E + 00

Table 4-14. INEEL worker radiation exposures.

Radionuclide	External Exposure (mR/y EDE)	Inhalation Exposure (mrem/y CEDE)	Total Exposure (mrem/y TEDE)
Evaporation pond contribution	5.73E - 06	2.73E - 03	2.74E - 03
Landfill contribution	7.89E + 00	6.08E - 04	7.89E + 00
Totals	7.89E + 00	3.34E - 03	7.89E + 00

The TEDE for the INEEL worker (0.008 rem/year) is less than the radiation dose limit of 0.1 rem/year identified for nonradiation workers and escorted public visitors.

4.9 Dose Estimates for the INEEL Visitor (Fence)

Radionuclide EPCs used for the landfill WAC were used for the INEEL visitor scenario. The ICDF Complex Landfill WAC concentration guides are utilized as they represent the maximum accepted value at the landfill that may be exposed to the visitor. It is assumed that the INEEL visitor is a member of the public who happens to watch activities from the fenceline near the landfill over a given day. Specifically, the frequency of the visitor's presence at the ICDF Complex was assumed to be 8 hours per day, 10 days per year, for 15 years.

The distance from the fenceline to the closest point within the ICDF landfill is estimated at 85 m (~250 ft). This distance is used to estimate the direct radiation exposure and the airborne concentrations originating at the landfill. The GXQ computer code was used to provide values for calculation of a DF at this distance. Table 4-15 illustrates the results of these calculations for the INEEL visitor.

Table 4-15. INEEL visitor radiation exposures.

Radionuclide	External Exposure (mR/y EDE)	Inhalation Exposure (mrem/y CEDE)	Total Dose (mrem/y TEDE)
Cobalt-60	1.40E - 19	4.86E - 05	4.86E - 05
Strontium- 90	0.00E + 00	6.72E + 00	6.72E + 00
Cesium-137	1.53E - 15	8.83E - 02	8.83E - 02
Europium-152	8.52E - 19	3.72E - 04	3.72E - 04
Europium-154	5.36E -19	3.15E - 04	3.15E - 04
Europium-155	4.04E - 21	1.53E - 05	1.53E - 05
Plutonium-238	0.00E + 00	1.10E - 02	1.10E - 02
Plutonium-239	0.00E + 00	8.58E - 03	8.58E - 03
Americium-241	0.00E + 00	1.28E - 02	1.28E - 02
Totals	1.53E - 15	6.84E + 00	6.84E + 00

The TEDE for the INEEL visitor (0.007 rem/year) is less than the radiation dose limit of 0.015 rem/year identified for nonradiation workers and escorted public visitors.

4.10 Highway 26 Rest Area Visitor

The unrestricted public exposure scenario considers exposure to a visitor located at the Highway 26 Rest Area. This unrestricted exposure scenario is a qualitative analysis based on the results of the INEEL visitor scenario. The INEEL visitor is in proximity to the ICDF Complex and shares the same source inventory and concentrations as the Highway 26 Rest Area exposed individual. The TEDE for the INEEL visitor is less than the radiation dose limit of 0.015 rem/year. Since the rest area is considerably farther (5,630 m) from the ICDF landfill than the location of the INEEL visitor (300 m), dose estimates calculated for the INEEL visitor would also be considered protective of the Highway 26 Rest Area visitor.

5. NONRADIOLOGICAL ANALYSIS RESULTS

As part of the risk assessment, the resulting risk estimates are compared with EPA target risk criteria. In interpreting estimates of ELCRs, EPA under the Superfund program generally considers action (e.g., modifications to engineered or administrative controls) to be warranted when risks exceed 1×10^{-4}. Action generally is not required for risks falling within 1×10^{-6} and 1×10^{-4}; however, this is judged on a case-by-case basis (EPA 1991). Risks less than 1×10^{-6} generally are not of concern to regulatory agencies. For purposes of this evaluation, the target risk level for carcinogenic risk is 1×10^{-4}. For noncarcinogenic COPCs, an HQ or HI greater than 1 indicates that there is some potential for adverse noncancer health effects associated with exposure to ICDF Complex COPCs.

This section summarizes the risk estimates for the identified exposure scenarios at the ICDF Complex.

5.1 Risk Estimates for the ICDF Landfill Exposure Scenarios

Potential exposure to soil was evaluated under this scenario, with the potential routes of exposure including incidental ingestion, dermal contact, and inhalation of vapors and dust. The following assumption was used to estimate potential RME for the landfill bulldozer operator, the landfill laborer (walking on landfill cell surface), and the landfill truck driver:

- A 70-kg adult was assumed to be exposed to soil from the ICDF Complex for 158 days per year, 10 hours per day, over 15 years.

The noncancer HI and ELCR estimates for the landfill scenarios are summarized in Table 5-1. Appendix D, Tables D-1 and D-2, provide the landfill risk calculation data.

Table 5-1. Summary of landfill risk estimates.

Exposure Scenario	Exposure Route	Noncancer HI	ELCR
Landfill scenarios	Ingestion	0.09	2×10^{-6}
	Dermal	0.01	8×10^{-7}
	Inhalation	0.33	6×10^{-6}
Totals		0.43	8×10^{-6}

The potential HI for noncancer effects is 0.4, which is below the regulatory threshold value of 1.0.

The potential cumulative ELCR from all carcinogenic COPCs is 8×10^{-6}, which is within the target risk range of 1×10^{-6} to 1×10^{-4}, but less than the target risk level of 1×10^{-4}. Chromium (65%; individual ELCR 6×10^{-6}) and arsenic (19%; individual ELCR 2×10^{-6}) are the primary contributors to risk.

5.2 Risk Estimates for the Treatment Unit Operator

Potential exposure to soil was evaluated under this scenario, with the potential routes of exposure including incidental ingestion, dermal contact, and inhalation of vapors and dust. The following assumption was used to estimate potential RME for the treatment unit operator:

- A 70-kg adult was assumed to be exposed to soil from the treatment unit for 200 days per year, 10 hours per day, over 15 years.

The noncancer HI and ELCR estimates for the treatment unit operator scenario are summarized in Table 5-2. Appendix D, Tables D-3 and D-4, present the treatment unit operator risk calculation data.

Table 5-2. Summary of treatment unit operator risk estimates.

Exposure Scenario	Exposure Route	Noncancer HI	ELCR
Treatment unit operator	Ingestion	0.15	3×10^{-6}
	Dermal	0.01	7×10^{-7}
	Inhalation	0.76	7×10^{-6}
Totals		0.92	1×10^{-5}

The potential HI for noncancer effects is 0.9, which is below the regulatory threshold value of 1.0.

The potential cumulative ELCR from all carcinogenic COPCs is 1×10^{-5}, which is within the target risk range of 1×10^{-6} to 1×10^{-4}, but less than the target risk level of 1×10^{-4}. Chromium (55%; individual ELCR 6×10^{-6}) and arsenic (43%; individual ELCR 2×10^{-6}) are the primary contributors to risk.

5.3 Risk Estimates for the Evaporation Pond Operator

Potential exposure to leachate was evaluated under this scenario, with the potential routes of exposure including inhalation of volatile emissions. The following assumption was used to estimate potential RME for the evaporation pond operator:

- A 70-kg adult was assumed to be exposed to leachate from the evaporation pond with two cells for 200 days per year, 2 hours per day, over 25 years.

The noncancer HI and ELCR estimates for the evaporation pond operator scenario are summarized in Table 5-3. Appendix D, Tables D-5 and D-6, present the evaporation pond operator risk calculation data.

Table 5-3. Summary of evaporation pond operator risk estimates.

Exposure Scenario	Exposure Route	Noncancer HI	ELCR
Evaporation pond operator	Inhalation	4	1×10^{-7}
Totals		4	1×10^{-7}

The potential HI for noncancer effects is 4, which is greater than the regulatory threshold value of 1.0. The primary contributors to the noncancer risk estimates are 2-nitroaniline (HQ = 1.3), 3-nitroaniline (HQ = 1.3), and 4-nitroaniline (HQ = 1.3).

The potential cumulative ELCR from all carcinogenic COPCs is 1×10^{-7}, which is less than the lower target risk range of 1×10^{-6} and less than the target risk level of 1×10^{-4}.

5.4 Risk Estimates for the ICDF Visitor

Potential exposure to soil was evaluated under this scenario, with the potential routes of exposure including incidental ingestion, dermal contact, and inhalation of vapors and dust from the ICDF landfill and the treatment area. Potential exposure to evaporation pond leachate was evaluated with the potential route of exposure including inhalation of dust and volatile emissions. The following assumption was used to estimate potential RME for the ICDF visitor:

- A 70-kg adult was assumed to be exposed to soil from the ICDF landfill, the treatment area, or leachate from the evaporation pond for 1 day each year, 8 hours per day, over 15 years.

The noncancer HI and ELCR estimates for the ICDF visitor scenario are summarized in Table 5-4. ICDF visitor risk calculation data tables are provided in Appendix D, Tables D-7 and D-8 (ICDF landfill), Tables D-9 and D-10 (treatment area), and Tables D-11 and D-12 (evaporation pond berm).

Table 5-4. Summary of ICDF visitor risk estimates.

Exposure Scenario	Exposure Route	Noncancer HI	ELCR
ICDF visitor	Ingestion	<0.01	3×10^{-8}
	Dermal	<0.01	8×10^{-9}
	Inhalation	0.09	6×10^{-8}
Totals		0.09	1×10^{-7}

The potential HI for noncancer effects is 0.09, which is less than the regulatory threshold value of 1.0.

The potential cumulative ELCR from all carcinogenic COPCs is 1×10^{-7}, which is less than the target risk range of 1×10^{-6} to 1×10^{-4} and less than the target risk level of 1×10^{-4}.

5.5 Risk Estimate for the CFA Office Worker

Potential exposure to modeled air concentrations was evaluated under this scenario, with the potential routes of exposure including inhalation of vapors and dust. The following assumption was used to estimate potential RME for the CFA office worker:

- A 70-kg adult was assumed to be exposed to fugitive dust and vapor emissions originating from a distance of 4,000 m from the ICDF Complex for 200 days per year, 10 hours per day, over 15 years.

The noncancer HI and ELCR estimates for the CFA office worker scenario are summarized in Table 5-5. Appendix D, Tables D-13 and D-14, present the CFA office worker risk calculation data tables.

Table 5-5. Summary of CFA office worker risk estimates.

Exposure Scenario	Exposure Route	Noncancer HI	ELCR
CFA office worker	Inhalation	<0.01	3×10^{-12}
Totals		<0.01	3×10^{-12}

The potential HI for noncancer effects is less than 0.01, which is less than the regulatory threshold value of 1.0.

The potential cumulative ELCR from all carcinogenic COPCs is 3×10^{-12}, which is considerably less than the lower target risk range of 1×10^{-6} and less than the target risk level of 1×10^{-4}.

5.6 Risk Estimates for the Delivery Driver

Potential exposure to modeled air concentrations was evaluated under this scenario, with the potential routes of exposure including inhalation of vapors and dust. The following assumption was used to estimate potential RME for the delivery driver:

- A 70-kg adult was assumed to be exposed to fugitive dust and vapor emissions originating approximately 100 m from the ICDF landfill and 63 m from the decon building for 200 days per year, 1 hour per day, over 15 years.

The noncancer HI and ELCR estimates for the delivery driver scenario are summarized in Table 5-6. Appendix D, Tables D-15 and D-16 (100 m from the ICDF landfill) and Tables D-17 and D-18 (63 m from the decon building), present the delivery driver risk calculation data.

Table 5-6. Summary of delivery driver risk estimates.

Exposure Scenario	Exposure Route	Noncancer HI	ELCR
Delivery driver	Inhalation	<0.01	4×10^{-9}
Totals		<0.01	4×10^{-9}

The potential HI for noncancer effects is less than 0.01, which is less than the regulatory threshold value of 1.0.

The potential cumulative ELCR from all carcinogenic COPCs is 4×10^{-9}, which is considerably less than the lower target risk range of 1×10^{-6} and less than the target risk level of 1×10^{-4}.

5.7 Risk Estimates for the ICDF Office Worker

Potential exposure to modeled air concentrations was evaluated under this scenario, with the potential routes of exposure including inhalation of vapors and dust. The following assumption was used to estimate potential RME for the ICDF office worker:

- A 70-kg adult was assumed to be exposed to fugitive dust and vapor emissions originating approximately 100 m from the ICDF landfill and 63 m from the decon building for 200 days per year, 10 hours per day, over 15 years.

The noncancer HI and ELCR estimates for the delivery driver scenario are summarized in Table 5-7. Appendix D, Tables D-19 and D-20 (100 m from the ICDF landfill) and Tables D-21 and D-22 (63 m from the decon building), present the ICDF office worker risk calculation data.

Table 5-7. Summary of ICDF office worker risk estimates.

Exposure Scenario	Exposure Route	Noncancer HI	ELCR
ICDF office worker	Inhalation	<0.01	5×10^{-9}
Totals		<0.01	5×10^{-9}

The potential HI for noncancer effects is less than 0.01, which is less than the regulatory threshold value of 1.0.

The potential cumulative ELCR from all carcinogenic COPCs is 5×10^{-9}, which is considerably less than the lower target risk range of 1×10^{-6} and less than the target risk level of 1×10^{-4}.

5.8 Risk Estimate for the INEEL Worker

Potential exposure to modeled air concentrations was evaluated under this scenario, with the potential routes of exposure including inhalation of vapors and dust. The following assumption was used to estimate potential RME for the INEEL worker:

- A 70-kg adult was assumed to be exposed to fugitive dust and vapor from the ICDF landfill for a total of 10 days per year, 8 hours per day, over 15 years.

The noncancer HI and ELCR estimates for the INEEL worker scenario are summarized in Table 5-8. Appendix D, Tables D-23 and D-24, present the INEEL worker risk calculation data tables.

Table 5-8. Summary of INEEL worker risk estimates.

Exposure Scenario	Exposure Route	Noncancer HI	ELCR
INEEL worker	Inhalation	0.02	3×10^{-7}
Totals		0.02	3×10^{-7}

The potential HI for noncancer effects is 0.02, which is less than the regulatory threshold value of 1.0.

The potential cumulative ELCR from all carcinogenic COPCs is 3×10^{-7}, which is less than the lower target risk range of 1×10^{-6} and less than the target risk level of 1×10^{-4}.

5.9 Risk Estimate for the INEEL Visitor

Potential exposure to modeled air concentrations was evaluated under this scenario, with the potential routes of exposure including inhalation of vapors and dust. The following assumption was used to estimate potential RME for the INEEL visitor:

- A 70-kg adult was assumed to be exposed to fugitive dust and vapor emissions originating a distance of 300 m from the ICDF Complex for 10 days per year, 8 hours per day, over 15 years.

The noncancer HI and ELCR estimates for the INEEL visitor scenario are summarized in Table 5-9. Appendix D, Tables D-25 and D-26, present the INEEL visitor risk calculation data tables.

Table 5-9. Summary of INEEL visitor risk estimates.

Exposure Scenario	Exposure Route	Noncancer HI	ELCR
INEEL visitor	Inhalation	<0.01	3×10^{-8}
Totals		<0.01	3×10^{-8}

The potential HI for noncancer effects is less than 0.01, which is less than the regulatory threshold value of 1.0.

The potential cumulative ELCR from all carcinogenic COPCs is 3×10^{-8}, which is considerably less than the lower target risk range of 1×10^{-6} and less than the target risk level of 1×10^{-4}.

5.10 Risk Estimate for the Highway 26 Rest Area Visitor

The unrestricted public exposure scenario considers exposure to a visitor located at the Highway 26 Rest Area. This unrestricted exposure scenario is a qualitative analysis based on the results of the INEEL visitor scenario. The INEEL visitor is in proximity to the ICDF Complex and shares the same source inventory and concentrations as the Highway 26 Rest Area exposed individual. The risk estimates for the INEEL visitor scenario are less than the EPA target risk level of 1×10^{-4} or an HI of 1.0. Since the Highway 26 Rest Area is considerably farther (5,630 m) from the ICDF landfill than the INEEL visitor (300 m), the risk estimates calculated for the INEEL visitor would also be considered protective of the Highway 26 Rest Area visitor.

6. MAINTAINING PERSONNEL EXPOSURES AS LOW AS REASONABLY ACHIEVABLE

The ICDF Complex will be managed to ensure that 1) acceptable short-term risk levels will be met for members of the community and nonradiation workers, and 2) Occupational Safety and Health Administration and DOE dose limits will not be exceeded for radiation workers. The primary methods used to control workplace exposure are facility and equipment design features. These controls are augmented with both area entry/exit requirements that control access to and from radiological areas, and radiological work permits that control radiological work. In addition, proposed maintenance and modification plans are reviewed to identify and incorporate radiological protection requirements. Additional discussions of the radiological controls implemented during the operations and maintenance of the ICDF are found in Section 3.7 of the *ICDF Complex Operations and Maintenance Plan* (DOE-ID 2003).

6.1 Planning of Radiological Work

The INEEL line management, with support from the INEEL Radiological Control organization, is responsible for performing radiological work planning, which involves incorporation of program requirements, planning documentation, survey results, and reviews. The INEEL program currently in place for the planning of radiological work contains the radiological review requirements. In conjunction with the work planning documents, the results of various radiological surveys are used to determine the radiological protection required. This level of protection is then identified in the Radiation Work Permits. For work that exceeds established planning thresholds, a formal as low as reasonably achievable (ALARA) review is performed.

6.2 Radiological Area Access

The INEEL's "Posting Radiological Control Areas Procedure" contains the specific requirements for entering and exiting radiological areas. Safe work and Radiation Work Permits function as the primary controls for entry into radiological areas. These controls are further augmented by signs and barricades.

6.2.1 Safe Work Practices

All employees, through their supervisors, have the authority and responsibility to stop unsafe work practices. Unsafe work practices can include radiological as well as nonradiological activities suspected of being unsafe as specified in the INEEL Site Contractor safety program.

6.2.2 Radiation Work Permit

The Radiation Work Permit is the administrative mechanism for establishing radiological controls for intended work activities. The Radiation Work Permit informs employees of area radiological conditions and entry requirements, and provides a mechanism to relate employee exposure to specific work activities.

6.2.3 Process for Entering and Exiting Radiological Areas

The INEEL process ensures that only trained and qualified personnel are allowed to enter radiological controlled areas and that these workers either have the information available to understand and respond to the radiological conditions that they may encounter during the work, or are accompanied by a trained escort. Radiation safety training commensurate with the hazards and required controls is required before unescorted access to radiological areas is permitted.

Radiological area entry and exit procedures include the use of the Radiation Work Permit, the use of electronic dosimeters (in some cases), and the use of an automated entry system that confirms the dose and training status of each employee prior to their entry into the radiologically controlled area.

The automated Radiological Control Information Management System is used to record entrance to or departure from the controlled area. Workers entering the area electronically log into the controlling Radiation Work Permits and are issued a supplemental dosimeter. The worker's radiological training and current dose are checked to ensure that the training is current and that the worker's dose are within current limits. Additionally, respiratory issue, current training, and fit test are checked if applicable.

During worker egress, the system then checks back in the electronic dosimeters and adds the dosimeter results to the worker's current total. The worker is also logged out of the Radiation Work Permits.

In the event that the automated system is unavailable (such as during system outages), a standby paper system is used until the system is operational.

6.2.4 Posting, Labeling, and Signage Controls

The established INEEL program ensures that radiologically contaminated areas, equipment, and material are appropriately labeled and/or posted. The purpose of these controls is to alert personnel of the radiological status of the item or area, and to prevent any inadvertent dose to the worker. This program uses standard radiological posting and labeling, and also ensures that signs are clearly and conspicuously posted.

6.3 Material and Equipment Controls

The INEEL program approach for controlling material and equipment is to consider all materials in contamination or airborne radioactivity areas contaminated until those materials have been surveyed and released. This program has been implemented to ensure that no material or equipment above the release limits is released from the control of the INEEL Site Contractor. The program controls the movement of material and equipment from contamination areas, and between controlled areas. The program also controls the release of material and equipment from controlled areas and from the INEEL site.

7. REFERENCES

10 CFR 835, 1999, "Occupational Radiation Protection," *Code of Federal Regulations*, Office of the Federal Register, January 1999.

40 CFR 300, 1994, "National Oil and Hazardous Substance Pollution Contingency Plan," *Code of Federal Regulations*, Office of the Federal Register, September 1994.

DOE, 1996, *INEEL Radiological Control Manual, Idaho National Engineering and Environmental Laboratory*, U.S. Department of Energy, 1996.

DOE, 2000, "Multi-Agency Radiation Survey and Site Investigation Manual," NUREG-1575, Rev 1; EPA 402-R-97-016, Rev 1; DOE/EH-0624, Department of Energy.

DOE-ID, 1990, *The Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1989*, DOE/ID-12082(89), Department of Energy Idaho Operations Office, 1990.

DOE-ID, 2002, *Waste Acceptance Criteria for ICDF Landfill*, DOE/ID-10865, Rev. 2, Department of Energy Idaho Operations Office, May 2002.

DOE-ID, 2003, *ICDF Complex Operations and Maintenance Plan*, DOE/ID-11000, Rev. 0, Department of Energy Idaho Operations Office, February 2003.

EDF-ER-264, 2002, "INEEL CERCLA Disposal Facility Design Inventory," Rev. 1, Environmental Restoration Program, Idaho National Engineering and Environmental Laboratory, December 2002.

EDF-ER-274, 2002, "Leachate/Contamination Reduction Time Study," Rev. 1, Environmental Restoration Program, Idaho National Engineering and Environmental Laboratory, May 2002.

EPA, 1986, "Development of Advisory Levels for Polychlorinated Biphenyls (PCBs) Cleanup," EPA/600/6-86/002.

EPA, 1988, "Limiting Values of Radionuclide Intakes and Air Concentrations and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," EPA-520/1-88-020, Environmental Protection Agency, Office of Radiation Program, Washington, D.C., 1988.

EPA, 1991, "Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals)," EPA/540/R-92/003, Environmental Protection Agency.

EPA, 1994, *Air Emissions Models for Waste and Wastewater*, Office of Air Quality Planning and Standards, Research Triangle Park, NC.

EPA, 1996, *Superfund Soil Screening Guidance: User's Guide*, Second Edition, Publication 9355.4-35, Office of Solid Waste and Emergency Response, Environmental Protection Agency.

EPA, 1997a, *Exposure Factors Handbook*, EPA/600/P-95/00s Fa, Environmental Protection Agency.

EPA, 1997b, Health Effects Assessment Summary Tables, Office of Solid Waste and Emergency Response, Environmental Protection Agency.

EPA, 1999, "US EPA Region 3 Risk Based Concentration Tables," Web page updated April, 1999, Web page visited August 20, 2002.

EPA, 2000a, Health Effects Assessment Summary Tables (HEAST) - Radionuclides Table, http://www.epa.gov/radiation/heast/. Web page updated April 16, 2001. Web page visited August 12, 2002.

EPA, 2000b, U.S. EPA Region IX Preliminary Remediation Goal Table www.epa.gov/docs/region09/waste/sfund/prg/index.html. Web page updated November 22, 2000. Web page visited August 20, 2002.

EPA, 2002, "The Integrated Risk Information System," www.epa.gov/iris/. Web page updated September 19, 2002. Web page visited August 12, 2002.

ICRP, 1975, "Report on the Task Group on Reference Man," ICRP Publication 23, *International Commission on Radiological Protection.*

INEEL, 2003, *Health and Safety Plan for INEEL CERCLA Disposal Facility Operations*, INEEL/EXT-01-01318, Rev. 0, Idaho National Engineering and Environmental Laboratory, Idaho Falls, February 2003.

MicroShield, 1998, "MicroShield User's Manual," Grove Engineering, 15215 Shady Grove Road, Rockville, MD 20850, 1998.

ORNL, 2001, "Risk Assessment Information Web Server," www.risk.lsd.ornl.gov. Web page updated March 5, 1999. Web page visited August 22, 2002.

WHC, 1994, GXQ, Version 4.0, Consequence Analysis, B.E. Hey, Westinghouse Hanford Company, WHC-SD-SWD-30002, Revision 1A, December 19, 1994.